REPORTS

OF THE

COMMISSIONERS OF THE UNITED STATES

TO THE

INTERNATIONAL EXHIBITION

HELD AT

VIENNA, 1873.

PUBLISHED UNDER DIRECTION OF THE SECRETARY OF STATE
BY AUTHORITY OF CONGRESS.

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VOLUME IV.

ARCHITECTURE; METALLURGY; GENERAL INDEX.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

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VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON THE

BUILDINGS OF THE EXHIBITION

AND ON

RAILROAD STRUCTURES.

BY

LYMAN BRIDGES,

MEMBER OF THE ARTISAN COMMISSION OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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THE BUILDINGS OF THE EXHIBITION.

CHAPTER I.

INTRODUCTION.

LOCATION AND EXTENT OF BUILDINGS AND GROUNDS; THE CITY OF VIENNA; THE INDUSTRIAL PALACE; ARRANGEMENT OF EXHIBITS; LOCATION OF SMALLER BUILDINGS; THE GROUNDS; ERECTION OF THE AMERICAN SCHOOL-HOUSE; THE AMERICAN DEPARTMENT; LOCATION OF SPACE AND OF EXHIBITS; NUMBER OF EXHIBITORS AND THEIR SUCCESS.

1. The plan of the International Exhibition at Vienna was conceived and executed under the most favorable circumstances. The government of Austria appropriated 22,000,000 of florins, or about $11,000,000. The location was all that could have been desired, in the Prater, which is a park of 4,000 acres, consisting of lawns, gardens, and forests. It is five times larger than the Champs de Mars, the site of the Paris Exposition of 1867, twelve times larger than that of London in 1862, twenty-two times larger than the Crystal Palace grounds in New York in 1852, and twenty-nine times those of the exhibition-grounds in Hyde Park, London, in 1851. It was directly connected with all parts of the city by steam or horse railways, excellent paved streets, or by steamers on the Danube. Rivers bound it on the north and east. The suburbs, Wieden and Leopoldstadt, which would be called wards in this country, bound the Prater on the south and west.

2. It is entirely within the city of Vienna, the capital of Austria, which is composed of nine towns which have been consolidated into one grand city of 1,100,000 inhabitants. The old town, covering but one-twentieth of the area of the present city, was formerly surrounded by an immense ditch and parapet which the present Emperor caused to be levelled, and a magnificent boulevard now beautifies its former site. Taxes are remitted for twenty years to any person building on this avenue. The American embassy was located on this boulevard, the Danube and Prater being in the foreground, and the exhibition occupying the best portions of the latter. The site of the main building is the imperial garden, surrounded by long-preserved forest-trees, lawns, fountains, and beautiful pavilions, built and occupied by enterprising people from all parts of the world. The city of Vienna is seen on a background, beyond which are the Soemmering Mountains.

3. The main exhibition-buildings extend from east to west 2,800 feet, and are 78 feet in width. The main central transept, extending through the rotunda, is 625 feet in length and 80 feet in width. There are also sixteen minor transepts, 540 feet in length, including the crossing of the east and west transept, and 47 feet in width. Between these transepts

are open courts, 100 feet wide, all of which were, either wholly or in part, covered with wooden pavilions by nations occupying the adjoining transepts.

4. The nations represented in the exhibition were placed in the same relative position in the building as they occupy on the globe, from east to west. Thus Japan, China, Turkey, Egypt, Russia, Greece, Hungary, Austria, Germany, Belgium, Holland, Sweden, Norway, Denmark, Italy, Switzerland, France, Spain, Portugal, Great Britain, Brazil, South America, and the United States were assigned space in the order named, Japan and the United States occupying the extreme eastern and western ends of the main buildings, and Russia and the United States occupying the extreme ends of the Machinery-Hall, with the other countries intervening, in the order of their geographical location.

5. The pavilions were located as nearly as practicable, in accordance with the same general idea, so that it was easy to locate the position of the exhibits of any nationality. The Machinery-Hall was located parallel with and north of the main buildings. The kunst- or art-hall was placed upon the eastern extension of the main buildings, its western, or nearest, line being 350 feet from the east portal. The buildings for the floral and horticultural exhibitions were about 500 feet south of the art-hall.

The exhibition of cattle, stock, and swine was held about one mile east of the main exhibition, in a portion of the Prater where ample provision had been provided for all applications for space. All the space allowed by the General Direction to be used for buildings was taken up and occupied.

6. The Deneral Direction transplanted all of the most valuable trees that it was necessary to move, and constructed streets, lawns, fountains, and sanitary arrangements, bringing city water and gas into the grounds. When it seemed impossible to complete the buildings and grounds by the 1st day of May, 4,000 soldiers were detailed, and they were finally completed and opened on the day appointed.

The great prosperity of, and enterprise exhibited in, manufactures and in architectural and building improvements, as well as in the beautifying of its numerous parks, gave sure promise of a result which should bear favorable comparison with the great Paris Universal Exposition.

7. In accordance with orders received from the United States Executive Commissioner, the writer shipped all the finished work of the American school-house, including sash and doors, from Chicago to Vienna, purchased the timber in Austria, and erected the building in the most eligible location to be found adjoining the United States department. The size of this building was 34 by 50 feet; 16 feet high. There were two principal rooms, one on either end, the school-room being 27 by 33 feet, and the recitation-room 15 by 33 feet. Each was lighted from three sides. This last room was used for a reception, reading, and writing room for Americans, and for the business-meetings of the General Commission. There were also two vestibules and cloak-rooms

between the principal rooms. There was a ventilating-cupola on the top of the building. Complete ventilation was secured throughout. The building was built of balloon-frame, sided outside, and neatly sheathed, and was papered inside. Blackboards were on the walls. The National School-furniture Company furnished forty-eight seats, which were placed in position for scholars, a teacher's desk, globes, books, charts, maps, and complete apparatus for illustrating everything taught in any district-school in America. The recitation-room had a carpet, tables, chairs, and desk. This was a rendezvous for Americans. The entire cost of this building was $4,813, which was within the amount specified in the order of General Van Buren; it was pronounced by all visitors the most complete school-room at the exposition.

8. THE UNITED STATES SECTION.—The American department, or the United States section, occupied the extreme western end of the main building, all of the western cross-transept, except about 100 feet of the north end, (which was assigned to South America and Brazil,) and the open court which was between the two southwestern transepts. This the United States covered. In the foregoing space Groups I, II, III, IV, V, VI, VIII, IX, X, XI, XII, XIV, XV, XVI, XVII, and XXIII were exhibited. The educational exhibit was made partly in the American school-house and partly in the main building. It was an honor to the country.

The machinery exhibit was located in the western end of the machinery-hall, and contained many ingenious and valuable exhibits. The exhibit of agricultural machines was made in a separate building adjoining the machinery department, and both here and in the field the exhibits of the United States were unsurpassed. The sewing-machine exhibit from the United States was located in a covered court between two transepts. It surpassed that of any other country.

In the fine-art exhibit, G. P. A. Healy, of Chicago, and A. Bierstadt, of New York, were honored with medals, justly-earned laurels. The former exhibited a portrait of Pope Pius IX and the Romanian princes; the latter presented his matchless views of American scenery.

9. While the representation from the United States included nearly twice as many exhibitors as were represented at the Paris exhibition in 1867, the magnitude of this exhibition was not understood, and the distance from America was so great that our countrymen did not comprehend its importance and the benefits to be expected to accrue to exhibitors.

Notwithstanding the lateness of the appropriation by Congress, the great distance to be travelled, and the fact that the articles for exhibition were transported by sailing-vessels, the United States department was opened by the middle of May, 1873. Our exhibitors obtained more than their share of the awards in proportion to the number of exhibitors.

CHAPTER II.

BUILDINGS OF THE EXHIBITION.

STYLE OF ARCHITECTURE; FOUNDATIONS; WALLS; GENERAL DIMENSIONS; DETAILS OF CONSTRUCTION; THE ROTUNDA; DESIGNER; DIMENSIONS; ELEVATING THE GREAT CIRCULAR GIRDER; FRAMING OF THE DOME; LANTERN; THE ART-BUILDING; MACHINERY-HALL; THE PAVILIONS; THE JURY; THE IMPERIAL, THE SCHWARZENBERG AND THE SAXE-COBURG-GOTHA PAVILIONS; SCHOOL-HOUSES AND OTHER ANNEXES; THE JAPANESE PAVILION AND THE PAVILION OF THE NEUE FREIE PRESSE.

10. The principal buildings erected by the Austrian government were in the renaissance style of architecture.

11. The site selected for these buildings has a peculiar alluvial bottom, a water-bed from the Danube, having a depth of 6 feet, which gives no stability to foundations, so that it was necessary to drive piles wherever buildings were erected. Upon these, grout was placed, and upon the grout, masonry was laid in cement well bedded in the grout, and carried up to the top of the ground, where the brick walls were started. The walls of all the main buildings were of brick, strengthened by pilasters. The main buildings were 2,800 feet in length, crossed by principal and minor transepts from 540 to 625 feet in length, and from 47 to 80 feet in width. Between these cross-transepts extended open courts, 100 feet wide on the north and south of the main east and west transept.

12. The outside walls were covered with cement-stucco, and the principal portion of the lower story was lined in imitation of stone. The roofs were arched and covered with zinc, having standing grooves. The inside walls of the transepts had columns 2 feet in front of the pilasters, these columns furnishing a finish to and division of exhibits; the walls being furred and covered with tinted canvas, stretched from the clerestory windows to the floor.

The principal portal was the south central entrance, opposite the grand entrance to the park. The north, the east, and the western portals were principal entrances. The transepts assigned to the different nations had each an entrance, over which their names and national seals were placed.

In the frieze and panels of the pilasters were inscribed names of noted artists, mechanics, engineers, and other celebrated men. Between the projections of the main center and the last, or end, double cross-transepts on both north and south fronts, there were in all twelve colonnades, 12 feet wide, flagged below and roofed above. These colonnades covered

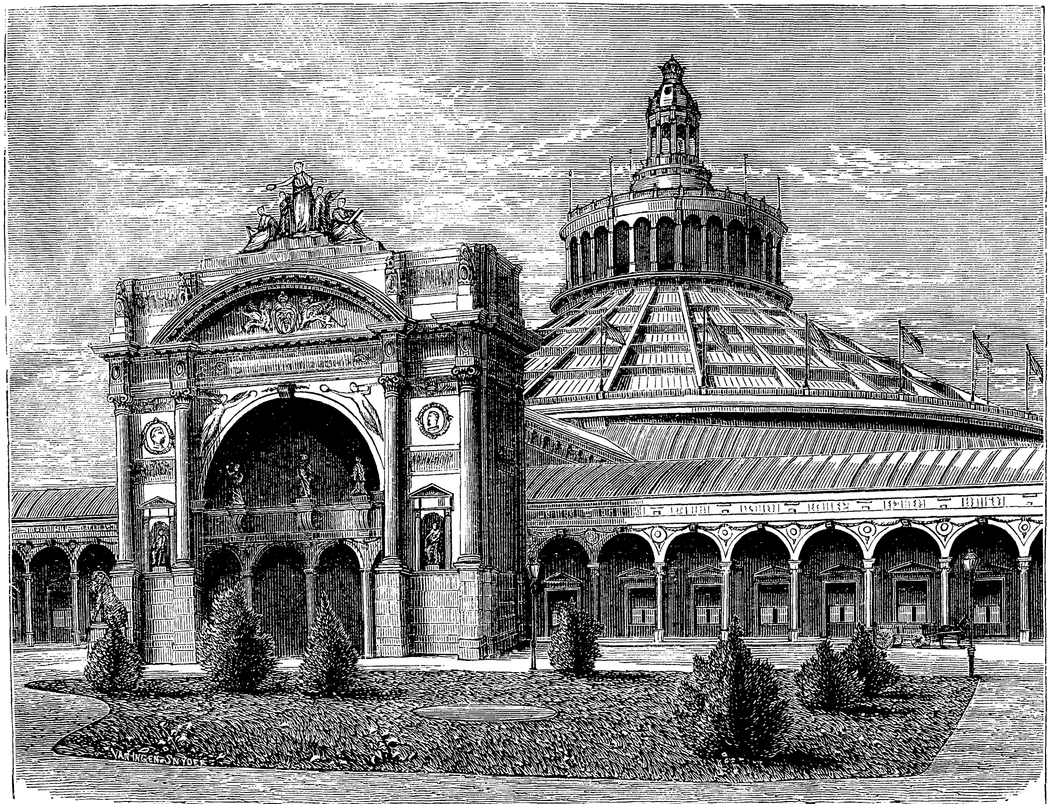


FIG. 2.—THE SOUTH PORTAL.

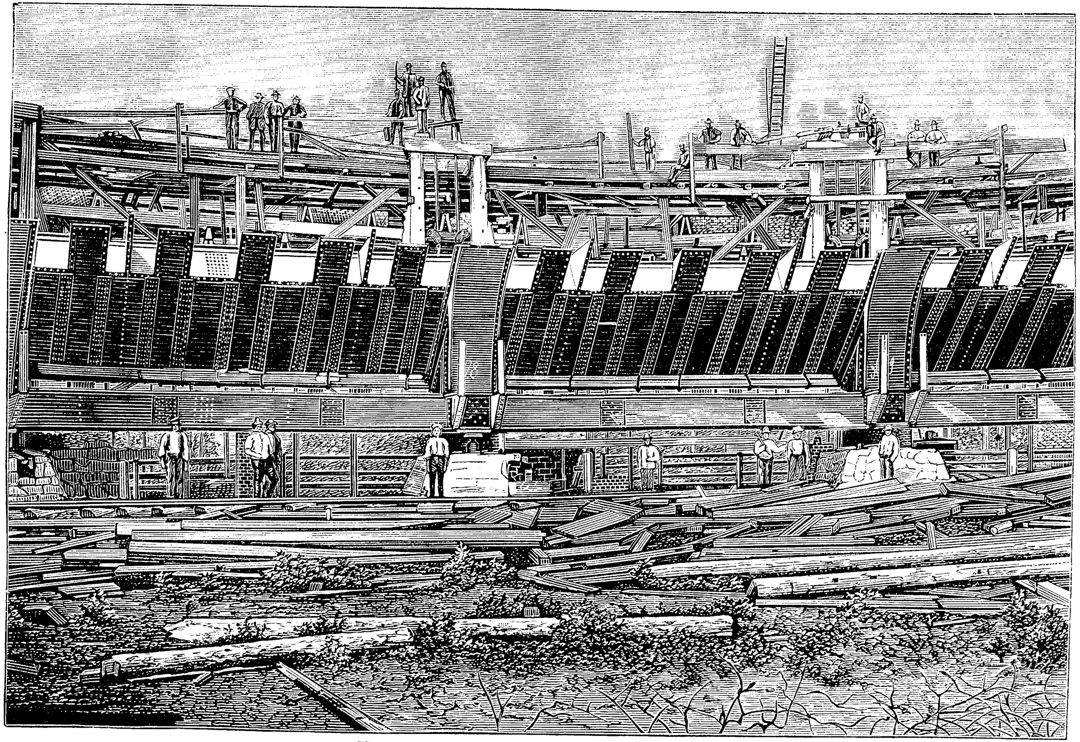


FIG. 3.—THE CIRCULAR DOME-GIRDER

the galleries connecting the two end and the two center transepts. These galleries were used for the sanitary, the clerical, and the police arrangements below, and for the officers of the commissions of the countries connected with them or whose exhibits were adjacent.

Fig. 2 shows the main entrance, with the coat of arms of the Austrian Empire, the colonnades, and the dome with the crown and lantern.

13. THE DOME.—Notwithstanding the many miles of courts and transepts through which we passed and admired for the symmetry and forethought of its arrangement, the great feature of the exhibition was the grand central dome, located at the center of the main buildings, and which constitutes a portion of the rotunda, a structure which has never been equalled in modern architecture. The dome was built from the designs of J. Scott Russell, the celebrated English engineer. It is built of iron, and weighs 4,000 tons. It is supported upon thirty-two pairs of double iron columns, 80 feet in height, each bearing a vertical pressure of 109 tons. They were incased in sheet-iron, giving the appearance of solid columns, 4 by 10 feet each. Inside of this ring of columns the dome has no support. The diameter of the dome is 354 feet, its circumference 1,080 feet, and its altitude 257 feet to the crown, or lantern, including which its total height is 284 feet. This is the largest rotunda in the world, being 3.17 times larger than the dome of St. Paul's Cathedral, London; 2.26 times larger than the dome of St. Peter's at Rome; 2.22 times larger than the dome of the International Exhibition Buildings at London. Upon this ring of columns rests an immense iron circular girder, or ring, which was riveted and bolted together on the ground, and raised by hydraulic pressure. The columns were placed in position as the ring, or girder, was raised. Fig. 3 shows the position of the girder as it was being raised.

14. The foundations of the columns were carried upon pieces of stone, supported on piles, and well laid in cement. They projected 4 feet above the surface of the ground. A railway-track was laid in a circle on the inside of the ring, upon which track cars were brought with the iron ring-girder completed in sections. The latter were placed upon the stone piers, or foundations, connected, and then hydraulic pressure was applied, and the ring began to ascend. As fast as the sections of the column could be inserted it was so placed. Fig. 4 shows the iron ring-girder raised to one half its full height. Fig. 5 shows the iron ring-girder after it has arrived at its destination, when the stagings are being finally replaced by sections of the columns.

15. It will be seen that the upper side of this ring-girder slopes at an angle of thirty degrees, which is also the slope of the cone; upon this circular rested the radial girders, which were each 200 feet long, and were riveted and bolted to the ring at the bottom and at each circular ring above. The columns on the east and west sides of the dome contained iron stairways and hydraulic lifts by which visitors ascended to the dome.

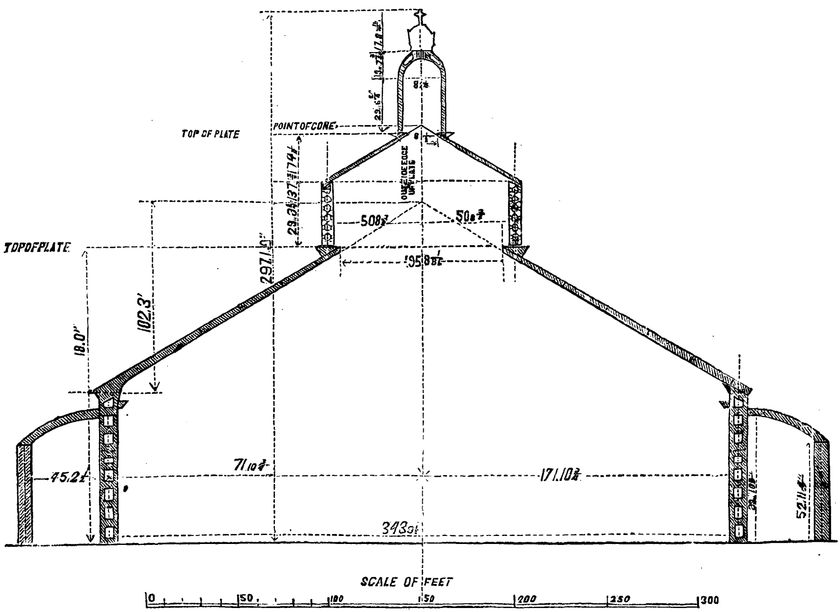
The design of the engineer was to build the cone from the lower ring-girder, thus avoiding the necessity of using staging; but the Austrian architect and engineer built a staging, as shown in Fig. 6, and placed the upper ring-girder upon this staging in the place designed for it. They then connected the radial girders from the lower ring-girder to the upper ring-girder, and the columns around the upper dome. The roof, between the radial girders, is composed of 360 iron plates, tapering uniformly upward from the circumference to the apex of the cone, and riveted together like the plates of a ship.

16. The upper dome, or lantern, is 100 feet in diameter, and is supported by thirty iron columns 50 feet in height. It is lighted by windows 40 feet high and 10 feet wide between the columns. It is surmounted by an imperial crown 60 feet in height, making the total height of the dome above foundations, (main columns, 80 feet; cone, 100 feet; windows, 40 feet; crown, 60 feet,) 280 feet. The foundations measure 20 feet additional.

The inside of the iron dome was lined with canvas in sections, laced together through rings under each radial girder. The canvas was painted to imitate fresco, the figures being 21 feet in length, or about four times the size of life, their great height making them appear but of natural size when seen from the floor of the rotunda.

Forming a part of the rotunda is an outer ring, or arcade, 40 feet wide and 80 feet high, opening into four charming gardens, or open courts, thus making the ground floor of the rotunda 440 feet in diameter.

FIG. 7.



CROSS-SECTION OF THE ROTUNDA OF THE VIENNA EXHIBITION.

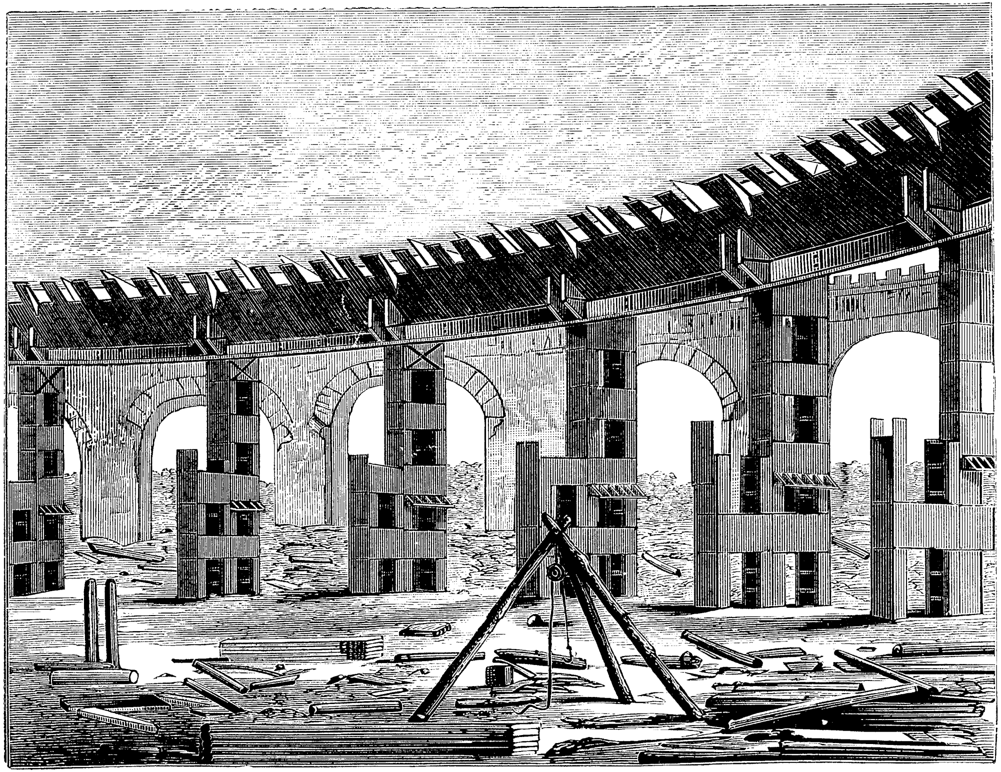


FIG. 4.—THE DOME-GIRDER PARTLY RAISED.

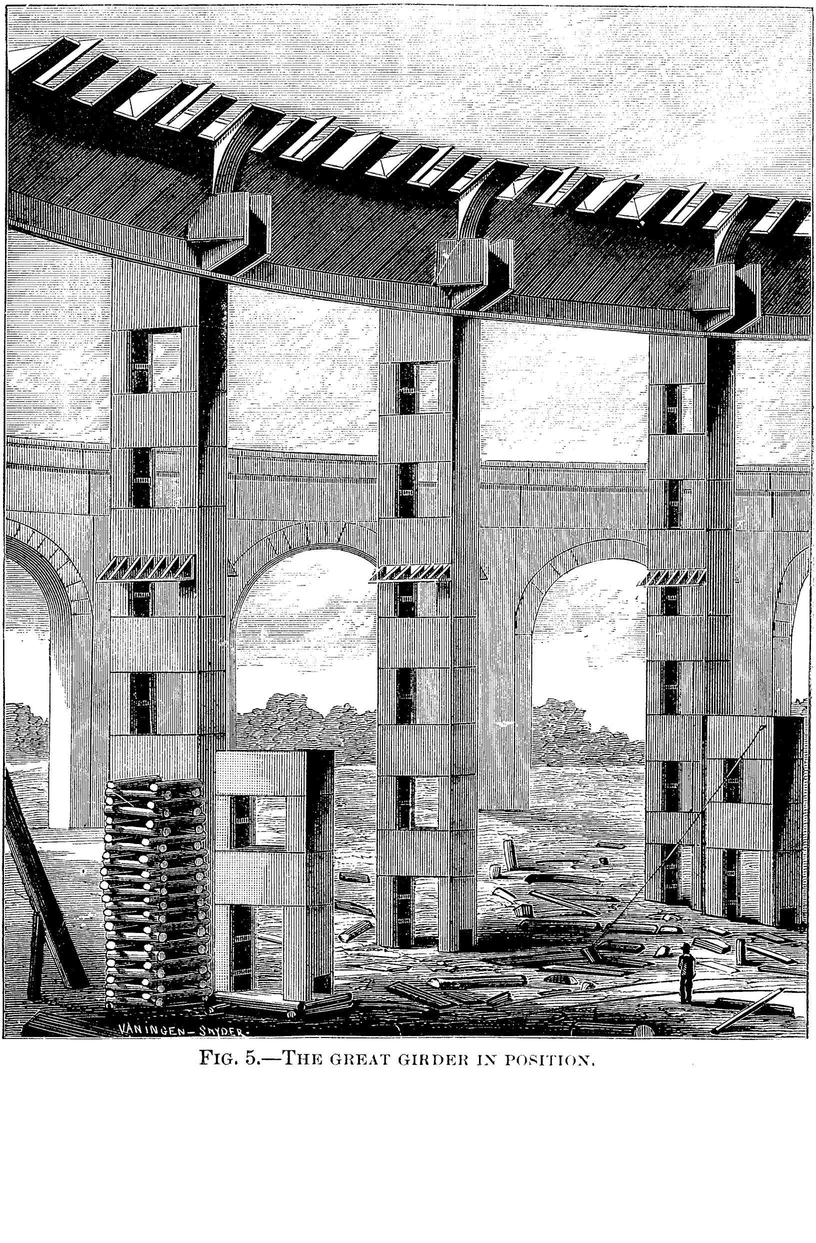


FIG. 5.—THE GREAT GIRDER IN POSITION.

The sketch, Fig. 7, shows the lower or main columns supporting the outward or lower ring-girder, upon which the frustum of the cone rested. There is also placed a second ring-girder to receive the pressure of the inner edge and to distribute the pressure around the cone. The columns become part of the cone itself, being connected both to the radial and the ring-girders, thus adding strength to each and to all parts by an ingenious system of iron chain-cables, or parabolic catenaries, ending in the summits of the columns supporting this dome The weight of the cone anchors the columns on the other side, and it is claimed that should an earthquake or any other power be sufficient to move this 4,000 tons of iron the whole structure would move bodily, including the columns. It is certainly the most grand, practical, and imposing dome the world has ever seen, and it is no less a triumph of skill and art in engineering. It is an illustration of the practical use of iron in one of the most difficult and scientific problems of architectural construction. The dimensions on Figure 7 are in metres.

18. THE ART-BUILDING.—The kunst, or art-hall, was east of the main building, standing in a north and south line, or at right angles to the main building, its nearest side being 350 feet east of the east portal. It was 100 feet wide by 600 feet long, with a large corridor at the center of sides and ends for the exhibition of statuary. The building was of brick, with the universal stucco-finish outside. The inside was divided into suitable galleries and studios, and was well lighted from the roof. In addition to the paintings, some of the choicest statues and statuettes were here exhibited.

In addition to the art-building proper, there were open wooden pavilions, connecting either end of the art-hall, extending 400 feet, with circular returns of 700 feet in length, and to the triumphal arch which completed the eastern end of the series of principal buildings. This last series of pavilions was almost wholly devoted to the exhibition of statuary, fountains, terra cotta, plaster, artificial stone, and similar materials.

19. THE MACHINERY-HALL.—The Machinery-Hall was 125 feet wide and 2,060 feet long, all in one room, 60 feet in height, having brick walls, the outside covered with stucco, colored so as to give it the appearance of bluestone; the roof was of iron, built light but strong. Two railway-tracks ran through the entire length of the inside, and with a parallel track on the outside gave excellent facilities for shipment of heavy machinery either to or from the exposition. The designs for the shafting were made by the Austrian engineer, and were all uniform. Each nation was given as much power as was desired.

20. PAVILIONS.—Among the pavilions surrounding the principal exhibition buildings were the imperial and jury pavilions, located on the east and west of the grand entrance. They were both of brick, finished in imitation of stone outside. The former, for the use of the imperial family, consisted of a reception-room, Emperor's room, Empress's room, arch-

duke's room, and ample ante-rooms, all on one floor. The interior decoration was replete with the products of artistic skill, both in design and in execution. The jury pavilion contained the assembly and committee rooms for each group. A portion of its structure was enlarged to two stories in height. The general direction and imperial commission pavilions were on either side of the grand, or main, entrance, and connected with a semicircular corridor connecting the main buildings. Ample provisions for telegraphing, reading, and writing were here afforded, and an interpreter for every nation was furnished by the General Direction.

21. The Schwarzenberg estate erected an extensive and symmetrical wooden pavilion, in the Swiss style of architecture, and filled this, besides covering all the ground adjoining and assigned to them, with the most complete exhibition of everything useful, either to eat, to wear, or for manufactures, that could be crowded into so small a space. The most noticeable articles were sugar, sirups, honey, beet-sugar, cereals, alcohol, spirits, fish, game, wool, flax, iron, steel, wood, lumber, every kind of wooden ware, and illustrations of the ceramic arts. This pavilion was designed and executed with great skill, and would repay many days of study. This estate is located in several parts of Austria and Germany, though mostly in Austria, and includes a greater number of acres than some of the states of this union. It is owned by Prince J. Adolphus Schwarzenberg of Vienna.

22. The pavilion of the Duke of Saxe Coburg-Gotha was next in size and in importance as a complete exhibition. It was also constructed in the Swiss style of architecture, built of wood, and with much skill and good judgment. Similar articles were exhibited to those shown as just described by the Schwarzenberg estate.

23. The United States, or American, school-house was adjacent to the Portuguese, Swiss, and Swedish school-houses, which were all built of wood, and smaller than that of the United States; that of the Swedish nation was in the form of a cottage. The largest room was used for the exhibition of samples of their text-books, desks, and articles made by girls. The German school-rooms were filled with drawings, models, and contained a few desks. The Persian, Turkish, Russian, French, English, and Egyptian pavilions, the light-house of the maritime board, the Swiss music-hall, a house of artificial stone, Wagner's stable, Wagner's green (iron) house, a water-tower (of iron,) the military barracks, Krupp's pavilion, the Russian peasants' house, and the American, Russian, Swiss, Swedish, Tyrolese, Austrian, English, and German restaurants were also erected in the Swiss style of architecture; and many others were objects of interest. Permits for the erection of about three hundred within the inclosure were granted by the General Direction, and as many more were erected without the inclosure and within the Prater.

24. The Japanese pavilions were made in their own peculiar style,

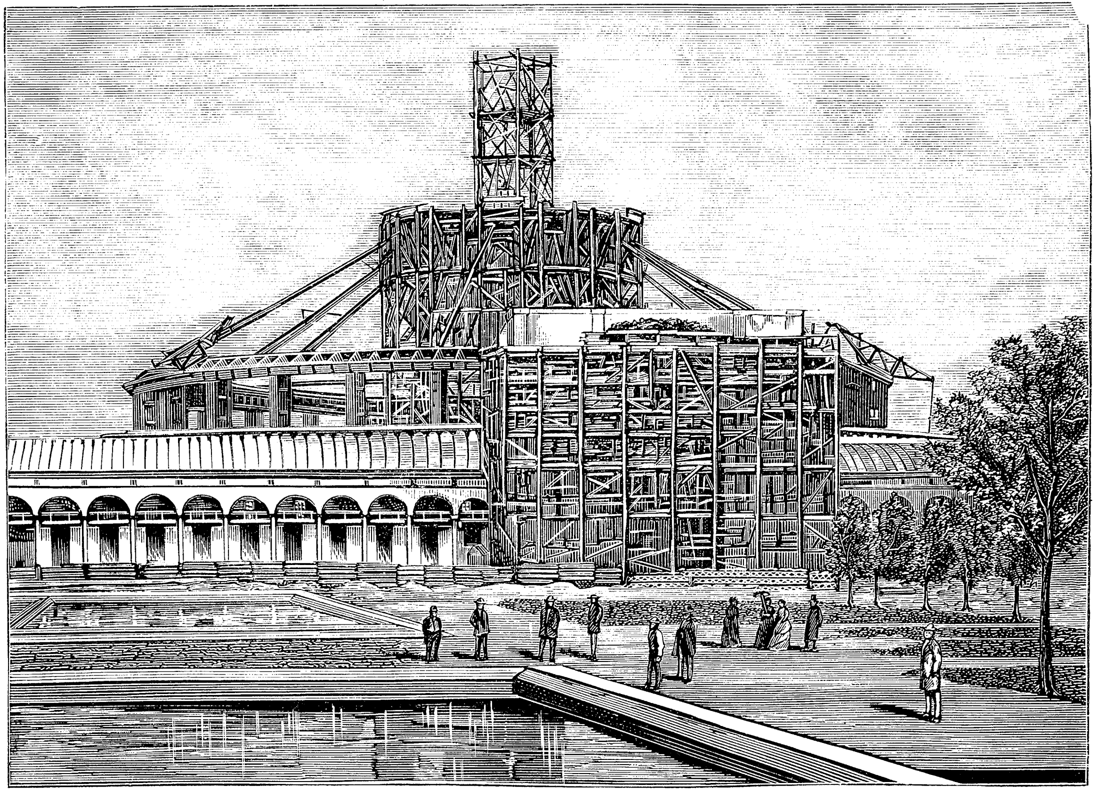


FIG. 6.—THE STAGINGS UNDER THE DOME.

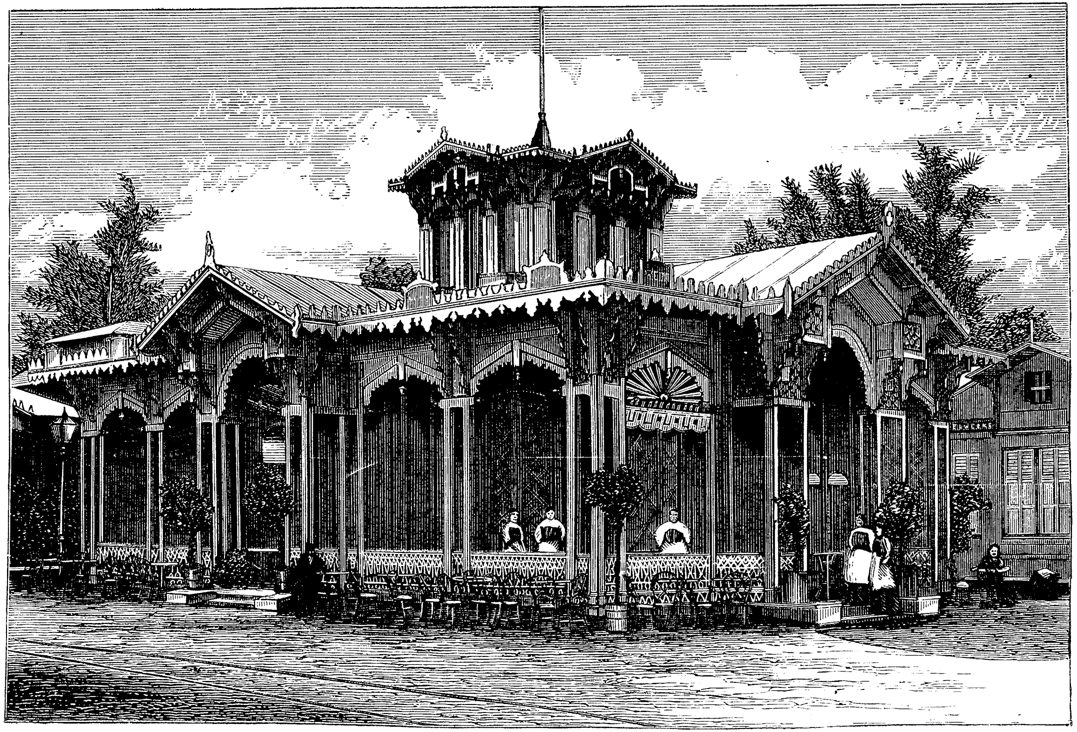


FIG. 8.—SWISS RESTAURANT.

with one story, and the universal veranda in front. The woods used were brought from Japan, and the buildings were erected by mechanics from Japan, who put them up in a masterly and skilful manner. It was almost impossible to discover a joint. One of their workmen, while drawing his plane toward himself, as is their custom when planing a piece of wood, made a shaving 26 feet long. One peculiar feature of these Japanese houses was that, while they were built strongly, their sides were entirely of paper except where strength was especially required. Their windows were of paper, also; their shingles were of palm-leaves, and were nailed on with wooden nails, or pegs, similar to those used in pegging a boot.

25. The Neue Freie Presse building was of brick, and had the form of a cross; the inside was finished with stucco, or cement, and lined in imitation of stone; a portion of the center had the appearance of being two stories in height. The newspaper to be published here, and for which this building was erected, was the earliest and most ardent supporter of the exhibition in the empire, and was the recognized organ of the General Direction, publishing daily in this building accounts of the latest current events. One of the most useful and most scientifically constructed structures within the exhibition grounds, was that of the Wagner iron green-house, erected near the floral and horticultural exhibition halls. The system of heating by hot water was excellent, the ventilation good, and light perfectly under control. The design was symmetrical and complete.

CHAPTER III.

BUILDINGS IN THE CITY OF VIENNA.

THE STRAUSS MUSIC-HALL; ARSENAL: ITS CONSTRUCTION AND ARRANGEMENT; APARTMENT BUILDINGS; MODELS; HEINRICHSHOF.

26. Fig. 10 represents the Strauss music pavilion, or hall, in the Volks Garten. One of the features of this pavilion is that the covered stand for the orchestra is octagonal, and is half without and half within the buildings, so that the music can be heard within or without, as the weather may permit the audience to sit outside or may drive them within doors. The Strauss band, of from seventy-five to one hundred performers, gave two concerts each day within the exhibition grounds.

27. The adjutant-general's department, the quartermaster's department, and ordnance department, of the empire, have all of their executive offices located at the arsenal, which is some two miles from the center of the city and immediately on the outer circle of the improved or newly built-up portions of the city. This arsenal has been pronounced by Gen. William T. Sherman to be the finest and most complete in the world. The grounds, both within and without the inclosure, were beautified by parks and fountains.

28. The imperial arsenal is built of brick, the outside being in the form of a rectangle, with projecting corners and centers, in the Tudor-Gothic, or castellated style of architecture, with battlements all around. It has thick walls, for defense against musketry. This building varies from 50 to 100 feet in width and from three to four stories high. The intermediate, or cross, buildings within the inclosure are quite as extensive as the outer buildings. One building is used as an art and military museum, with all the war relics and articles captured from the enemy during hundreds of years past. On the walls and ceilings are painted the successful battles of the Austrian empire. At the main entrance of this military museum a hall, or corridor, is devoted to the exhibition of full-sized statues of the great generals and of the Emperors and Empresses of the empire.

Great care is taken to exhibit the keys of captured cities—in former generations the symbols of possession.

The foundery and machine-shops for the manufacture of large guns and of small-arms and of gun-carriages, an immense carpenters' and wheelwrights' shop, a harness and saddlery shop, and, in fact, the manufacture of all war-materials, are provided for in buildings within the arsenal.

The government has established a chapel at the center of one end of the inclosure.

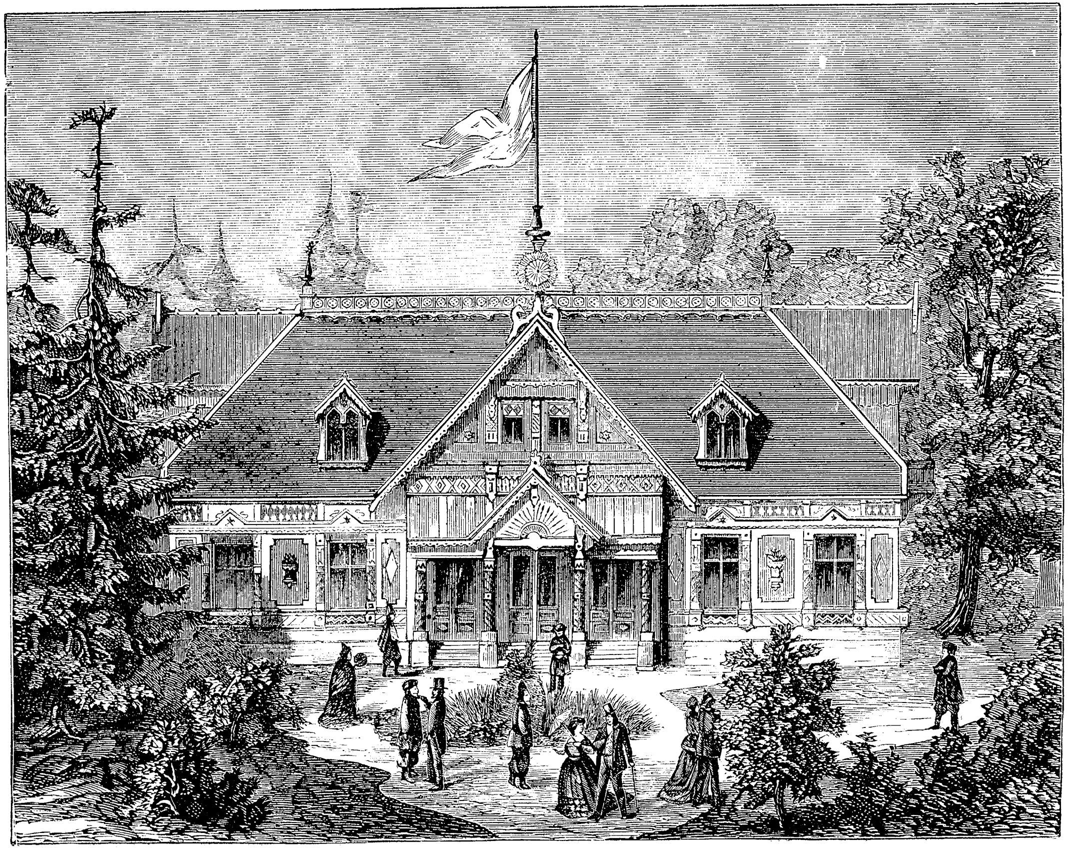


FIG. 9.—RUSSIAN RESTAURANT.

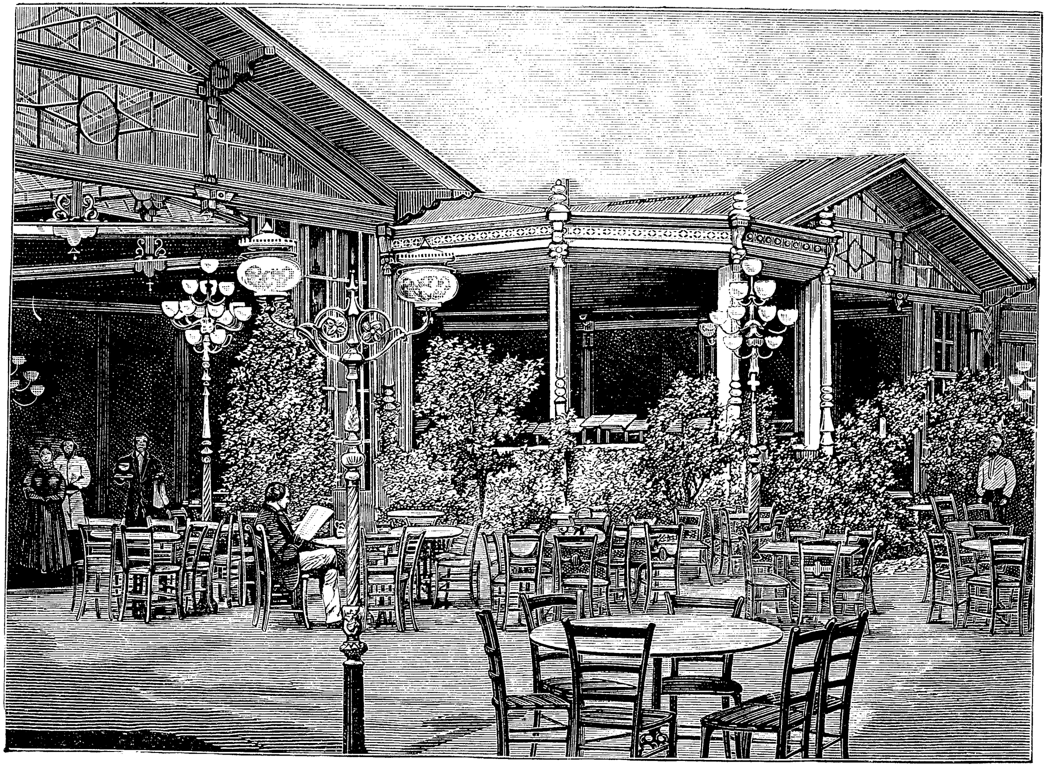


FIG. 10.—STRAUSS MUSIC-HALL.

29. APARTMENT-BUILDINGS.—Models and plans of apartment-buildings were exhibited from Great Britain, France, Germany, and Austria. Those from London, Berlin, Paris, Pesth, and Vienna claimed the most attention. Perhaps the most notable models were from Pesth, Hungary, where blocks and buildings on both sides of whole streets were shown, nearly all apartment-houses, of from four to six stories in height, and all masonry fire-proof buildings.

30. Fig. 12 shows a representative apartment-building fronting on the grand boulevard, or Ringstrasse, in the city of Vienna, and known as the Heinrichshof, (Henry House.) It covers an area of 150 by 310 feet, is six stories high at the centers and corners, and elsewhere five stories high. A cellar extends under the entire building. The lower story is occupied by *cafés*, or shops, and all above first story are used for apartments, usually suites of rooms. The best suites have bath-rooms and all sanitary accommodations, all arranged complete on the floor occupied. This building has a capacity for one thousand persons above the stores, or first floor. The buildings are built of brick and are fire-proof, the floor-girders being of iron, with brick floors, and the roof of tiles. There are sixteen flights of stone steps with iron railings, all distinct, from bottom to top. There are three open courts, say 60 by 200 feet inside, running across the building and between the outside walls. These courts give light and ventilation, and are connected with the streets by large arches of sufficient dimensions to admit a large carriage. Twenty carriages could enter the courts without inconvenience. Over one of these courts, above the second-story windows, a glass room has been erected, and an extensive restaurant fitted up in connection with the *cafés* at either side of it. The other courts are paved and kept open, and the janitor is compelled to keep them clean. The entrances to the apartments are through the arched passages. A janitor lives in rooms at the foot of the stairs at the entrance, whose duty it is to attend, day or night, and to receive messages when the occupants are absent, and to keep the keys when not occupying the rooms. Any number of rooms are leased as desired. Meals are served in the apartment *a la carte*, or occupants may come down to the restaurant in the first story or to the *café*, as preferred. Families left in their apartments can always call upon the porter for anything required or for protection. In many similar buildings the hydraulic lift, or elevator, is now placed, the city water-works pressure being sufficient to operate it without steam. The operation is so simple that a child can manage it, and the upper stories of apartment-buildings are thus made as available as the lower and more expensive stories.

Adjoining this main building, an apartment-building has a chapel with a hall in the second story. The American embassies in Vienna, Paris, and Berlin are in apartment-buildings. These buildings combine all requisites both for business and for residence, and in thickly-settled cities must come into general use.

CHAPTER IV.

THE CONSTRUCTION OF BUILDINGS.

SUPERINTENDENCE; GENERAL CONSTRUCTION; SPECIAL DEVICES; BUILDING-MATERIALS; ARTIFICIAL STONE; PLASTERING; LUMBER; CEMENTS; PRESERVATION OF TIMBER; BRICK-MAKING; APARTMENT KILNS.

31. When a building is to be erected that is of sufficient importance to justify the employment of an architect, the plans and specifications are completed by him, and a competent superintendent is employed, who proceeds to erect an office upon the grounds immediately adjacent to the place where the building is to be erected. This superintendent makes plans of all the details, and remains upon the ground until the building is completed, the architect, or engineer, giving his instructions to the contractors through this superintendent.

32. Iron girders, extending from the walls or partitions, are almost universally used to support brick arches, upon which the floors are laid. Brick partitions are usually built upon these girders and arches. The stagings erected around the buildings are much more extensive than those used in this country. They usually build them six feet or more in width for each story, and have inclines from one story to another, allowing them to remain until the completion of the building. The stagings contain almost as much lumber as many American buildings.

The foundations receive careful attention, and for a heavy masonry building are always placed upon piles and grout. All buildings are intended to be fire-proof from the ground to, and including, the roof. The walls are either brick, stone, or iron. The stair-ways are of stone, artificial stone, or iron, or brick, with cement covering and facings. Roofs, whether of slate or tile, are laid in cement. The flues, for ventilation, smoke, and ashes, are often made of hollow tile; in fact, many walls and ceilings are made of hollow brick, the ceilings being laid in stucco or plaster.

33. In one instance, in Vienna, we saw a building being erected where the joists were logs split in the middle, having a diameter of from 10 to 16 inches. This face was laid downward on the walls and brick partitions; cement was laid on top until there was a surface sufficiently level to permit the tile-floor to be laid above. The under side was covered with a net-work of rushes, and secured by wire well nailed to the face of the logs above. Upon this lathing of rushes the plastering was finished. The mortar is mixed in wooden boxes, and that, as well as the brick and tile used on the building, is usually carried to the place

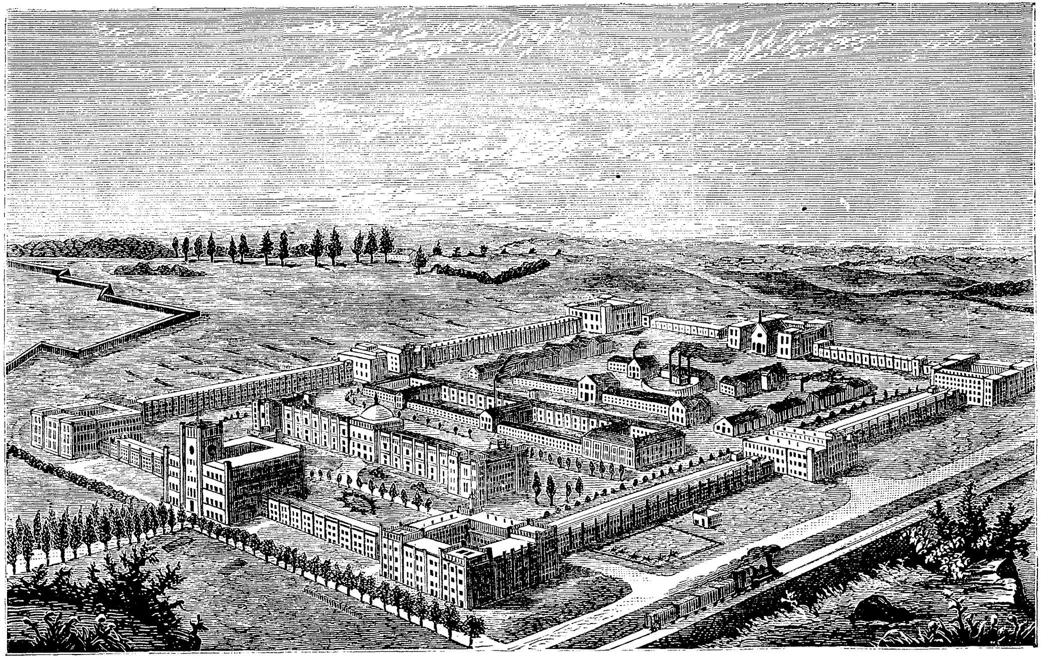


Fig. 11.—Imperial Austrian arsenal.

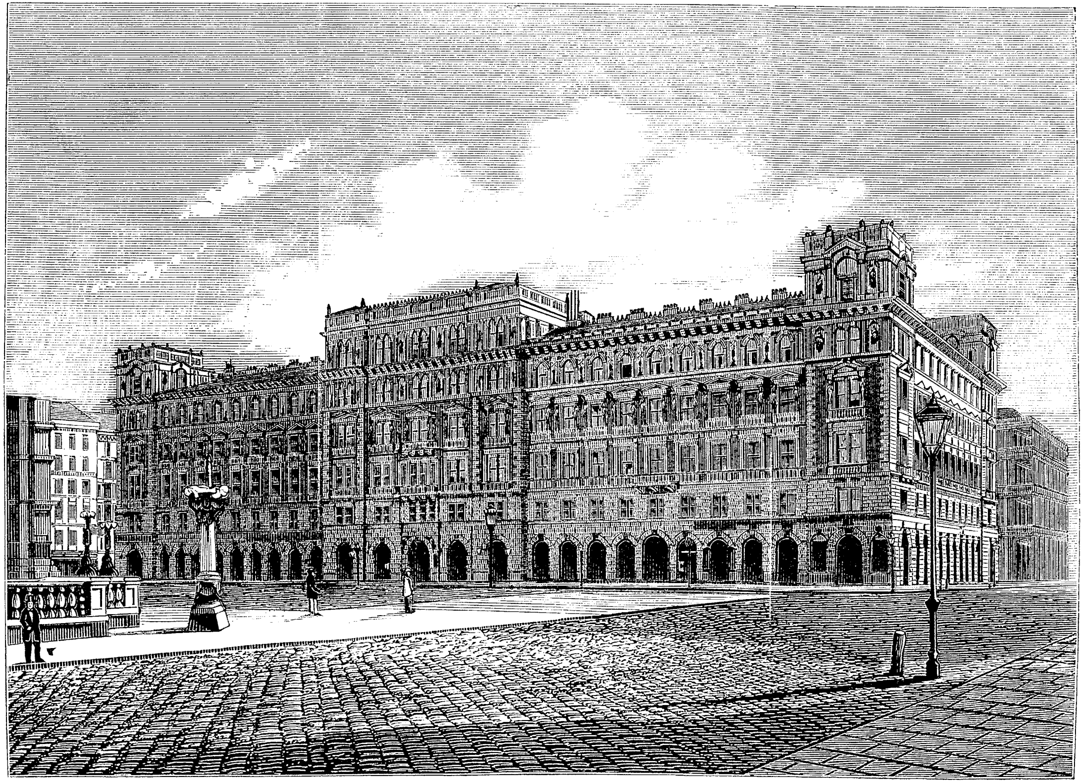


FIG. 12.—HEINRICHSHOF.

where used by women. The buildngs, which are built of brick and faced with stucco outside, are sometimes painted when completed, and are usually renewed and painted once in from three to five years, so that a freshly-finished appearance is given to buildings erected many years since.

34. BUILDING-MATERIALS.—Building-materials of all kinds were exhibited by every European country. Even Japan sent some excellent samples of wood, stone, iron, and pottery. The stone used in the exposition buildings and grounds by the Austrian government is a magnesian limestone, of a durable nature, obtained from inexhaustible quarries on the banks of the Danube, above the city of Vienna.

The exhibition of artificial stone and of terra cotta was probably superior both in quality and quantity to any similar collection ever before brought together. Great Britain, France, Germany, Italy, and Austria vied each with the other in the endeavor to produce the most substantial, elegant, and artistic specimens of this art. Great Britain and Germany excelled in the production of stone possessing the first-named quality. The Chailly artificial-stone house from Germany, 16 by 20 feet inside, had a roof of only 6 inches thickness in the center and 12 inches thick at the sides, with the arch of 6 inches rise, and no support in the center. We saw twenty men standing on the flat top, making no perceptible impression upon it. This building, of which the walls, floor, and roof were entirely of artificial stone, had another noticeable feature in the steps outside. Twelve steps were made in one piece, and the entire twenty steps were made in only two pieces. A report upon the artificial stone and terra cotta exhibited, alone would profitably occupy the entire space allotted to this report; but as the duty of describing these articles was assigned to another commissioner, a more extended notice need not be given here.

35. PLASTERING.—Plastering is used very extensively on walls and ceilings. Walls are very seldom painted inside. As the walls are usually of brick inside, much of the plastering is given a stucco or plaster-of-Paris finish in a larger number of coats than is usual in this country. Many buildings have one or more coats of brown mortar before the hard-finish is put on. Many columns and pilasters are finished with plaster of Paris, then painted in imitation of stone or of marble; and it is so well done that it is sometimes difficult to determine whether it is an imitation or the real article. In some cases, when the flat side of timbers, as previously described, were used to support floors, rushes were secured to their under side by having wires nailed to the timbers overhead, then the ceilings were plastered.

36. LUMBER.—A large proportion of the lumber used in Vienna is brought from the country in the vicinity of the Salzburg Alps and down the Danube. It consists of fir and of a species of pine, similar to our Norway pine, having a harder grain than our Michigan white pine.

The Schwarzenberg estate and that of Saxe-Coburg-Gotha, and some

Hungarian exhibitors showed some choice specimens of hard wood, the latter especially; and the French department also exhibited some beautiful specimens of walnut and ash veneering.

37. CEMENTS.—A very fine representation of water-lime and hydraulic cements was shown from Austria, Germany, Great Britain, Italy, and Spain, and several specimens came from the United States. The Roman and Portland cêments were best represented in the British section.

38. The Austrian cement most used, and the standard in Vienna, was manufactured about fifteen miles above Vienna, on the Danube. It has the following composition:

Water	0.50
Lime	58.50
Magnesia	3.55
Silicate of magnesia	0.30
Iron	6.60
Clay	4.75
Carbonic acid	0.50
Sulphuric acid	2.10
Potash	0.95
Flint-dust	18.60
Clay and sand	3.65
	100.00

This hardens under water in about thirty minutes, and in less time above water. Buildings faced with it two hundred years ago are now standing in the city of Vienna. The majority of buildings built in that city are constructed with large, coarse brick, and with thick joints outside, so as to give a good bond to bind the cement or stucco facings. They are almost universally faced with cement in imitation of stone. The window sills, caps, corbels, and cornices are in many instances built of burnt clay and cemented over, the corners and moldings formed in molds like the inside stucco or hard-finish work in this country. The aim seemed to be to have all outside cement-work done as early in the season as possible, that it may become hard before the frosts occur.

39. PRESERVATION OF TIMBER.—In the exhibit of timber and railway-ties, by several processes of preservation, it was demonstrated that the life of timber was extended four or five times. Over fifty patents have been obtained in England alone for processes intended to prevent the decay of wood. France and Germany have also granted patents for the same purpose. Some have aimed to prevent wet-rot and some dry-rot; and, from the year 1737, when the first attempt was made, up to the present time, boiled oil, corrosive sublimate or chloride of mercury, (kyanizing,) sulphate of copper, sulphate of iron, chloride of zinc, and the sulphate of iron with a succeeding application of carbonate of soda, which is said to form oxide of iron in the pores of the wood, have all

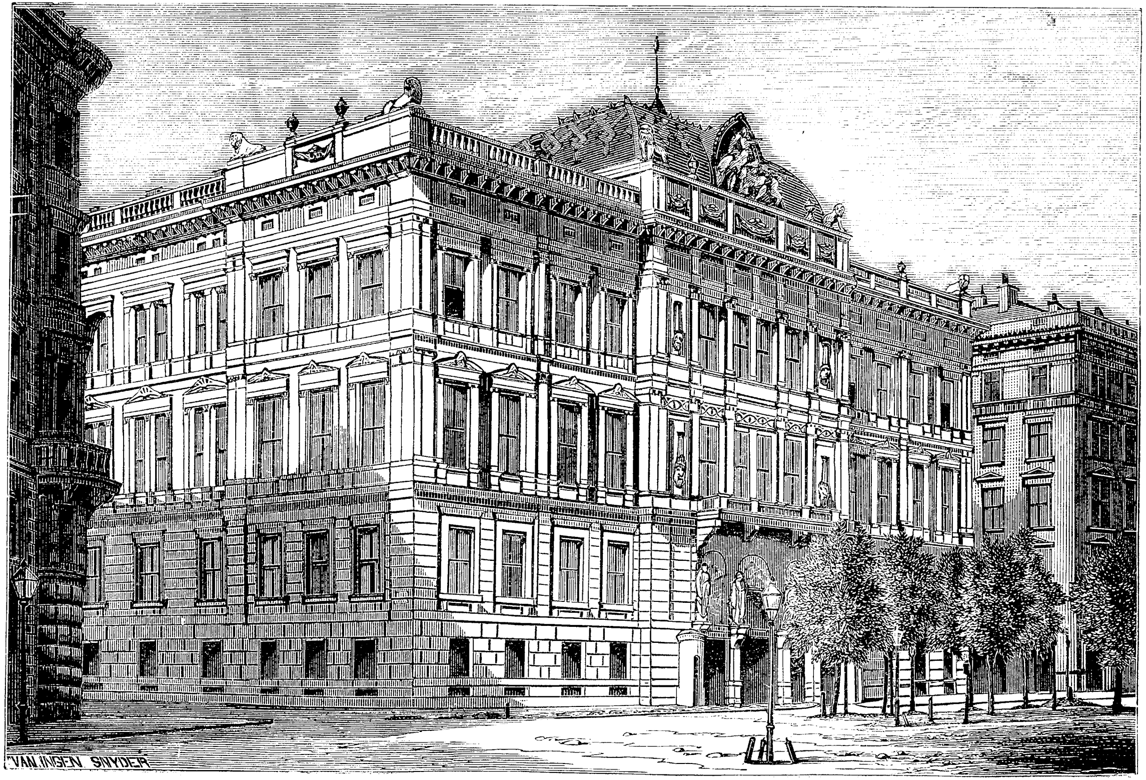


FIG. 13.—IMPERIAL HOTEL.

been tried. These methods were fully examined, and after inspecting specimens illustrating the use of several processes, and particularly a railroad-tie from Germany which had been in use for over fifteen years, which seemed just as good as the day it was cut, and which was warranted to last ten years more, it was concluded that the process of creosoting, by which this tie was preserved, was the best of all those observed. The process consists in placing the timber in an iron boiler, similar to a steam-boiler, from 25 to 75 feet long and 6 feet in diameter, and closing the boiler, extracting the air by an air-pump. When the vacuum-gauge indicates a vacuum of 20 inches of mercury, the creosote, which is stored in tanks adjacent to the boiler, is admitted at a temperature of 120° F., and fills the cylinder to within about 2 inches of the top. A pressure of from 100 to 150 pounds per square inch is then applied, the pressure being determined by the nature of the timber and the quantity of the creosote required to be introduced. One cubic foot of timber will absorb a gallon of creosote, weighing ten pounds. From four to eight hours is considered a sufficient time for creosoting ordinary timber.

We found railways in Austria, Germany, Italy, France, Belgium, and Great Britain using creosoted ties altogether; and after collating all the information obtained from engineers and master-mechanics, we found the cost to be from 12 to 20 cents (gold) for creosoting each tie. The average length of use was twenty-one to twenty-five years. In some instances, creosoting was advised for ties and piling, and burnetizing for bridge and building timber.

40. Brick-making.—The process of brick-manufacture and all kinds of clay-burning for building purposes, as exhibited by Austria and Germany, is a great improvement over the methods usually adopted in the United States. The brick are made either by hand or by machinery, then dried or baked until they can be handled easily, and until there is room in some of the compartments of the kiln for a charge.

41. The principal yards have permanent kilns built of brick, either circular or in the form of an ellipse, and made in compartments, each of which has a separate entrance and independent connection with the chimney. A down draught is secured from the top, where the fuel is placed, to the chimney, which is either built within the kilns or entirely outside, but which has its draught invariably connected with the bottom of the kilns. The fuel used is generally fine coal, which falls around all the bricks, and the flame and heated gases surround and pass through all portions of the materials being burned. While some of the compartments are being burned, others are being filled and still others being discharged. The proprietors of a large brick and tile works at Vienna informed us that their kilns had not been without fire in some portion for fourteen years. At one side of these kilns an approach, or incline, was constructed, so that wagons could deliver coal on the top of the kilns, precisely where it would be required in feeding.

FIG. 14.

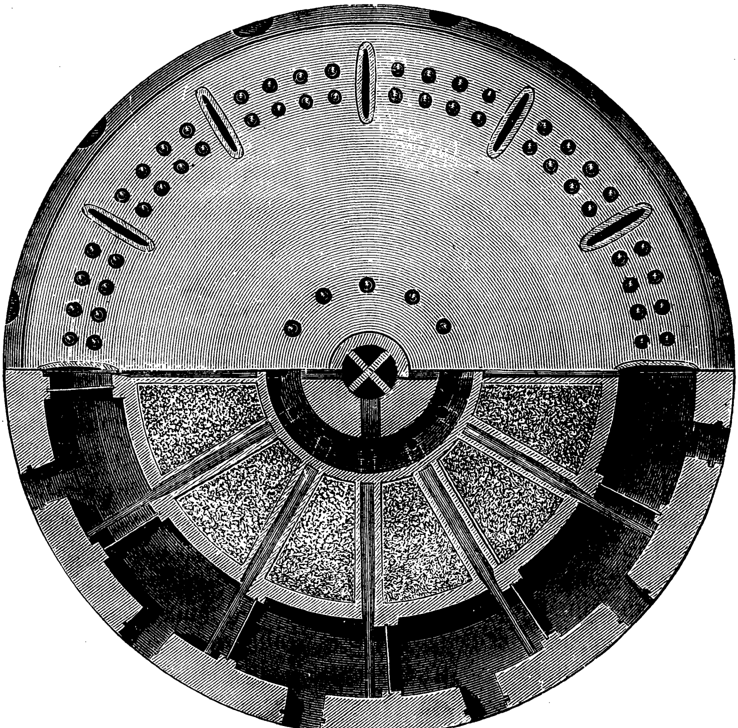


FIG. 15.

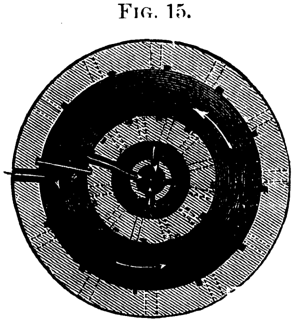


FIG. 16.

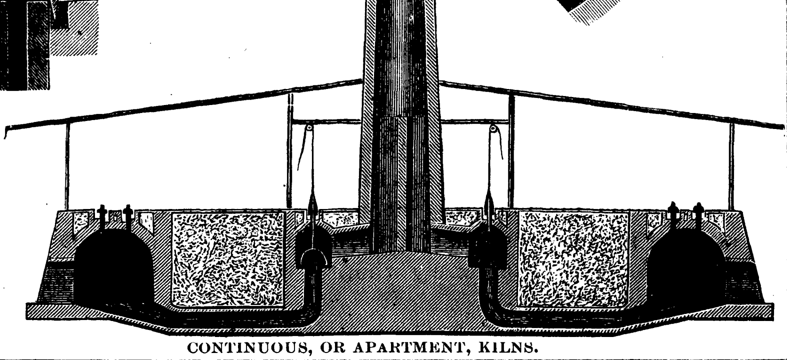


FIG. 17.

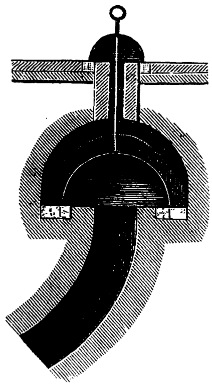
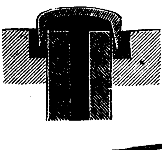


FIG. 18.



CONTINUOUS, OR APARTMENT, KILNS.

FIG. 19.—NORTHWESTERN RAILWAY STATION, VIENNA, AUSTRIA.

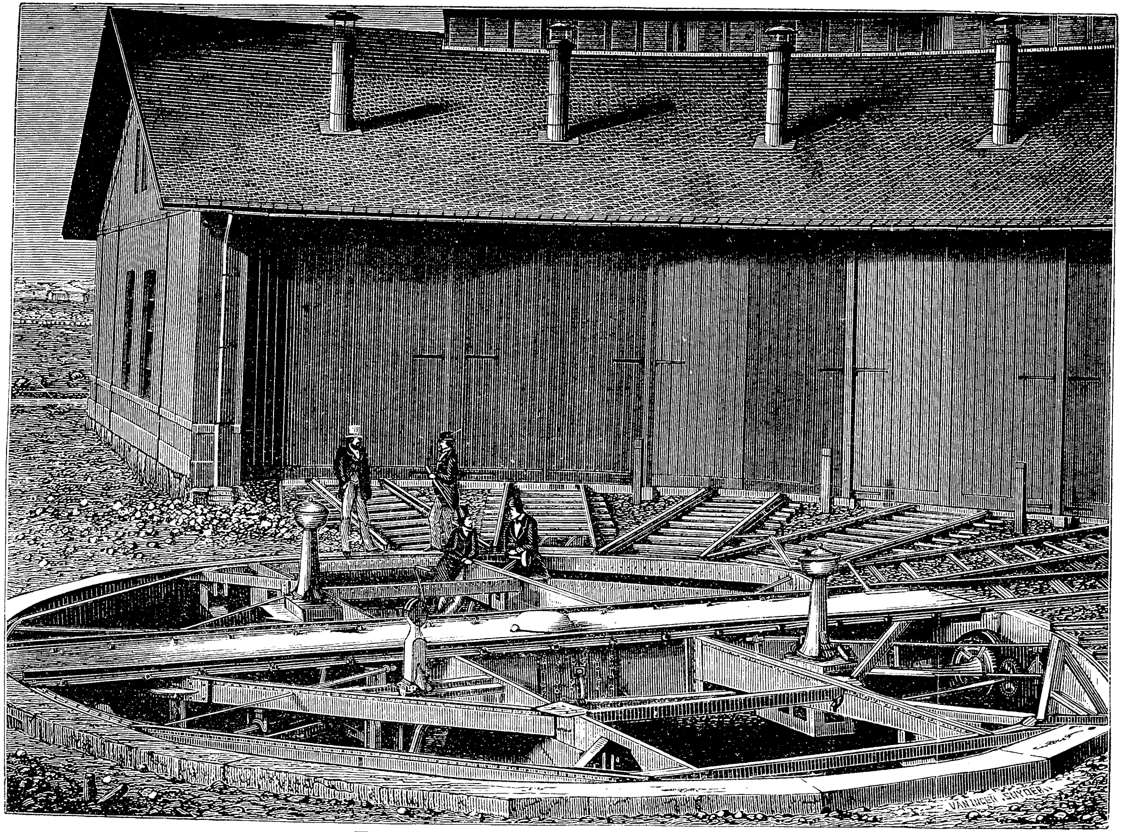


FIG. 20.—ENGINE-HOUSE AND TURN-TABLE.

42. Engravings showing the plan and sections of these kilns are here given. (Figs. 14–18.)

It is claimed that great economy is attained in the use of fuel, and that time is saved in burning clay for building purposes:

1st. By the diminished amount of fuel required.

2d. By the correct regulation of the draught, by draught-rods and dampers connected with the chimney.

3d. That all heat not required for the burning of any number of kilns, or compartments, can, by the system of the circular ovens and draughts, be used in other compartments.

The ring-oven is a continuous annular canal, with brick arched roofs, having an outer wall and a covered space to protect the ovens from the weather without. The doors of the compartments are made air-tight when the compartment is filled and its contents being burned. The compartments have connecting doors made in a similar manner, so that two or more compartments can be worked together if desired. The theory is also advanced that the coal is converted largely into gaseous combustible compounds to a certain degree, and thus a flame is obtained which more thoroughly permeates the mass of brick to be burned.

43. The size of the bricks exhibited and burned at Vienna was from four to seven times the size of those usually manufactured in the United States. They were thoroughly burned, and cost about one-half as much as an equal number of cubic feet made in the United States.

The same construction of kilns answers for the burning of lime and cement, with the single exception that for lime and cement the kilns are lined inside with fire-brick on account of the greater heat required, although some of the manufacturers in Austria recommend a fire-brick lining in all these kilns. About two thousand of their large bricks are placed in 320 cubic feet, which has been found practically to be the most economical proportion.

CHAPTER V.

RAILROADS AND THEIR CONSTRUCTIONS.

EXHIBITS BY RAILROADS; SUBSIDIES; CHARACTER OF CONSTRUCTION; DETAILS; SAXBY & FARMER'S SWITCH; AUSTRIAN RAILROAD-SIGNALS; CONCLUSION.

44. The principal railway companies of Austria and Germany were represented at the exhibition. The Northern, Western, State, and Southern railways of Austria made the best display, having each a pavilion devoted to the exhibition of their superstructures and railway-plant, as well as their management.

The Northwestern Railway Company erected a model station, having full-sized tracks and rolling-stock. Elevations of their principal depots and other buildings were exhibited, showing excellent plans for construction. One especially noteworthy detail was their simple and apparently perfect system of tickets.

45. The government of Austria, in order to secure for military purposes the completion of the trunk railway-lines centering in Vienna, has guaranteed 5 per cent. upon their cost of construction. This indorsement has not been abused, and but a single railway has ever received anything from the government on this account. This assistance has had the effect of increasing the total length of road during the past ten years from 8,500 miles to 28,155 miles of first-class railway in operation at the present time. Double tracks are laid down, with rare exceptions, with masonry viaducts and masonry or iron bridges. The grades are kept within a low maximum by constructing numerous tunnels and viaducts. The roadways are kept in good condition by trenches 5 feet wide and at least 2 feet deep on both sides of the road-beds, with cross-culverts, built of stone where practicable.

The foundations of the road-beds consist of large paving-stones or rubble-stone about a foot in thickness. Upon this foundation, which serves as a medium of drainage also, broken stone is placed up to and levelled to receive the ties. The spaces between the ties are then filled with the same material. After the iron is laid down, the center of the track is ballasted with small stone, making the center of the track level with the top of the rails, and a space is left under the center of each rail for water to escape through. When broken stone cannot be obtained, gravel is used for ballasting in the same manner above the bottom of the tie.

The road-bed is extended at least 2 feet outside of the ties, and great care is taken that the slopes are uniform and continuous. The ties are

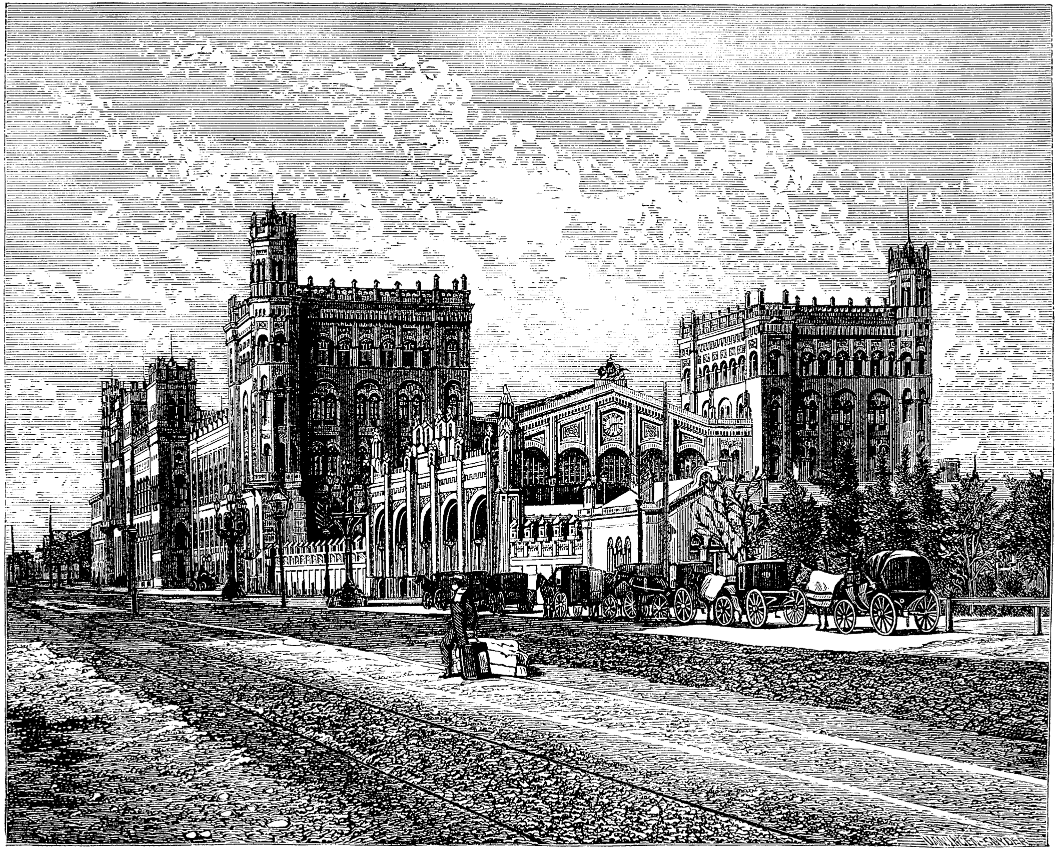


FIG. 21.– NORTHERN RAILWAY STATION, VIENNA.

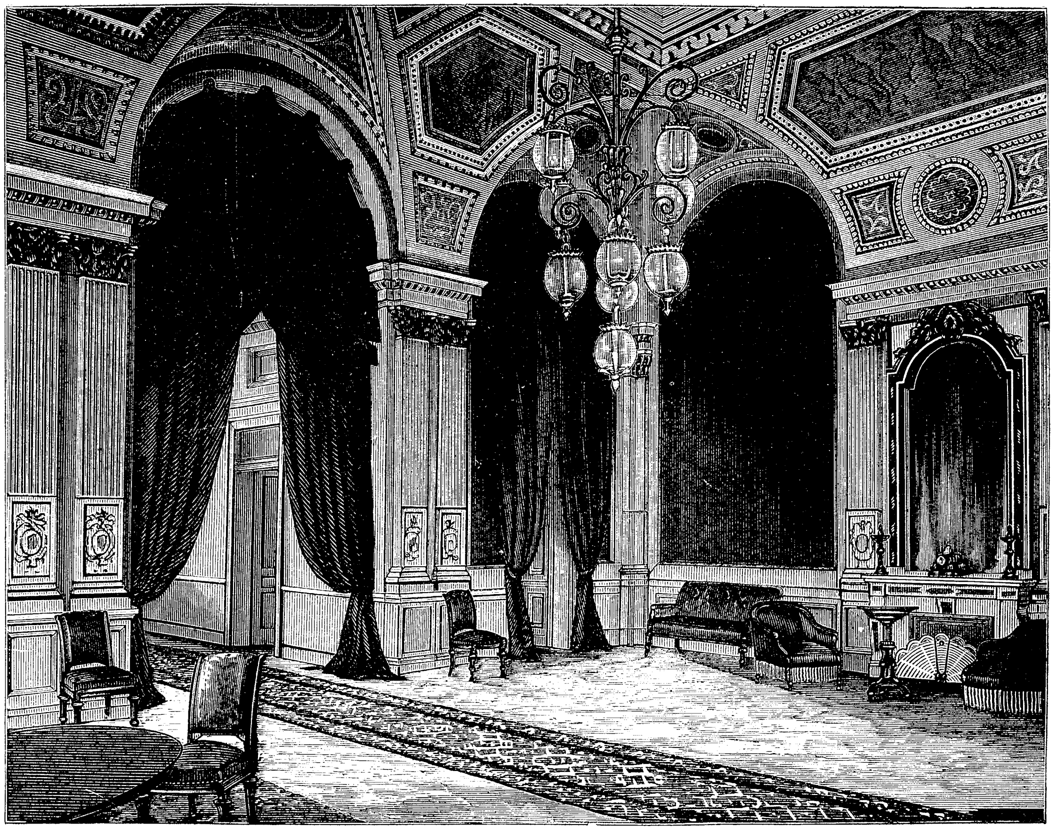


FIG. 22.—IMPERIAL APARTMENTS AT THE STATION.

usually 9 feet feet long by 5 or 6 inches thick and at least 10 inches wide. Baltic fir is generally used.

The cuts through which the Austrian railways pass are sloped evenly and turfed, and the embankments are also turfed or paved. When turfed, the employés keep the grass cut to prevent fires. When the cuts are of quicksand or of a treacherous nature and danger of land-slides exist, cross-hedges are planted so that the roots shall take hold of the soil and keep the surface from sliding down and filling the trenches. Sometimes the cuts have paved gutters, at intervals of 50 to 100 feet, to conduct the water coming down the face of the cut to the trenches. At considerable altitudes, when obstructions by snow are anticipated, rows of trees are planted at the top on either side of the cuts.

46. In exhibit 152 of group 18, in the German department, was shown a continuous cast-iron railway-tie, to be laid lengthwise the track, with the rail placed upon the tie, and four iron bolts extending through from one rail to the other. The tie was 12 inches wide and of iron three-eighths of an inch thick, and bolted to the rail every 2 feet. Great durability and economy was claimed for this device.

The Southern Railway, extending between Vienna and Trieste, has larger viaducts and a greater proportion of embankments paved with stone than any other that we found.

The railways of Austria have swing or lift gates at all road-crossings where viaducts are not practicable.

The North Railway Station at Vienna, as illustrated in Fig. 21, is one of the large stations at that city. It is, perhaps, as complete as any, and is located at the Prater-Stern, at the main entrance of the Prater. It has six tracks, under an iron and glass roof, between the main buildings. The buildings on either side of the main tracks are built in the Norman style of architecture, varying from three to five stories in height, are of brick, and look like a castle, as seen from the outside.

The department for baggage, the waiting-rooms, and the *restauration* arrangements are well arranged within the buildings next the street. The corresponding building, across the tracks, is occupied by the general offices of the company, and behind it is the freight department. This railway, as well as several other of the main lines, have, as one of its principal features, an Emperor's suite of rooms, consisting of a reception-room, (Fig. 22,) ante-room, and cabinet or closet arrangements. It is decorated and furnished beautifully, and has handsome carpets. When the imperial family arrive or depart, a carpet is stretched from the cars to this suite of rooms, and from the rooms to the carriages.

47. One of the most interesting modifications of railway switches was exhibited in the British section by Messrs. Saxby & Farmer, who showed a very elaborate model of their safety-switches and signals. An operator is located in the upper story of a building, which is usually about 8 feet wide and as long as required for the number of switches to be controlled. The building has windows on all sides. Upright levers,

resembling locomotive reversing-levers, are here placed along the center line of the room. Beneath the floor are weights and counter weights, and the heavy rods and wire cords that connect with the various signals and switches which are operated from this point, and which extend frequently a half mile on either side of the signal-station. The levers are all numbered, and each one bears the numbers of all other levers which must be moved before it can be itself moved. The lever moves the signal for the switch before the switch is changed. The operator has a chart of all the switches, signals, and tracks on the wall before him, and in addition he has a telegraphic chart immediately before him which shows the present location of all approaching trains. A black lever moves the switch-points by a line of positive connection of bell cranks and rods connecting with a bar between the two points; a blue lever governs the locking-mechanism which holds the latter in place. A similar line of connections leads to a long pivoted plate, lying beside one rail which, when the lever is changed, rises up like one side of a parallel ruler, above and to one side of the rail, and then swings over to its new position. The plate connects with a three-way crank, and the latter with bolts which shoot into the cross-piece between the points. The car-wheels prevent the possibility of the plate swinging over during the passage of a train. Red and green levers manage the home and green signals, and, by suitable wire cords, either turn the lights by night or lower the semaphore arms by day.

We had witnessed the operation of this ingenious mechanism in Manchester and in London, England, where one man controlled, in the former place, about fifty signals and switches, and in the latter place over a hundred. The manipulations were at the rate of thirty signals and switches (with all their points) per minute. It was all done with such perfect precision that it seemed almost impossible that an accident should occur. This subject is well worth the consideration of the railway managers of America.

48. The Austrian signal-service was adopted by a congress of railway officials in October, 1872, and is most complete in its operations both by day and night. Observation-houses, in which sentinels are stationed, are built on every mile, and oftener when many curves occur, and no train is allowed to pass one of these stations unless the track is clear for one mile ahead, the information being communicated by telegraph. Very complete books of explanation and instruction are published by each company for the guidance of all employés. There are two kinds of signals in general use, one called the visible, or optical, and one called the audible, signals. During the day-time the hand signal-flag (Fig. 23) is usually used; sometimes, however, the hand signal-disk (Fig. 24) is used. The lantern is used in the evening. Figs. 23, 24, 25, 26, and 27 are used to stop trains. In addition to the above, the disks in the day-time and red lanterns in the night are sometimes placed in the center of the track, the disk standing at right angles with

the track. To slacken speed, the signal-man holds out a red flag horizontally, facing the train, as in Fig. 28; or he holds out the hand signal-disk, turning its surface toward the train but outside of the track, as shown in Fig. 29; or he plants the disk in the ground, at the same place and in the same position as held above. He uses the green lantern in the night in the same manner as in Fig. 31. In the absence of any flag the arms are extended facing the approaching train, as shown in Fig. 30. Sound-boxes, or torpedoes, are placed on the track in the night when no lantern is at hand. When the road is free and clear, the signal-man faces the track with the red flag wound on the pole or staff, (Fig. 32,) or the red signal-disk is held facing the track, (Fig. 33.) In the night, the white lantern is held against the train, as in Fig. 34.

Fig. 35 represents the signal-post with its arm extended upward at an angle of 45°, which signifies that the road is clear. When the signal-post, (Fig. 36,) is used for signaling trains to stop, the arm is placed in a horizontal position at right angles to the track. For slackening speed, the arm of the signal-post is depressed at an angle of 45° and at right angles with the track.

In Fig. 36 is shown the changing illuminated signal which is attached to switches. The same colors and movements of the signals answer for the day-time.

A similar system of train-signals for the movement of all trains, and the disks and other signals, are placed before or on the locomotive and on the rear end of the rear car of each train. Another kind of visible signals is called the optical telegraph, consisting of signal-posts with movable baskets with cross and flat disks and arms. The baskets are placed in position as required by the rules of the company. Figs. 37, 38, 39, 40, 41, 42, and 43 are the principal positions of the baskets. In the night, lanterns are placed in the baskets and a similar system is used.

The audible signals are: Sound-boxes; steam-whistle of the locomotive; signal-whistle; signal-trumpet; station-lock; electric clock-work; electric signals.

The electric signals are perfectly arranged, and under the control of one person at headquarters, and are connected with every signal-station on the line. Each signal-man has a key, and, even when not a telegraph-operator, he reports to headquarters by taps the position or passage of trains at his station, and receives orders in the same way. The possibility of two trains trying to pass each other on the same track, as is attempted sometimes in this country, cannot occur.

49. Conclusion.—In conclusion, the International Exhibition at Vienna, in 1873, was a grand success. In its great advancement of art and science, and in the benefits accruing from it to each nation taking part, it has met all reasonable expectations. To none were the benefits so great as to the Austrian nation. Many claimed it to be a failure because the receipts at the gates were not equal, by about $4,000,000, to

the cost of construction and management. This was not the case. Several times that amount was left in the empire by foreigners during that year, and business connections were consummated which insured that, even as a matter of dollars, no loss was sustained. The education of the people of the empire, who literally poured into Vienna by excursion-trains, was worth all that the exhibition cost the Austrian government. The Austrian officials, it is a pleasure as well as a duty to add, were untiring in their courteous attentions to foreign representatives, and no request was made to them that was not granted.

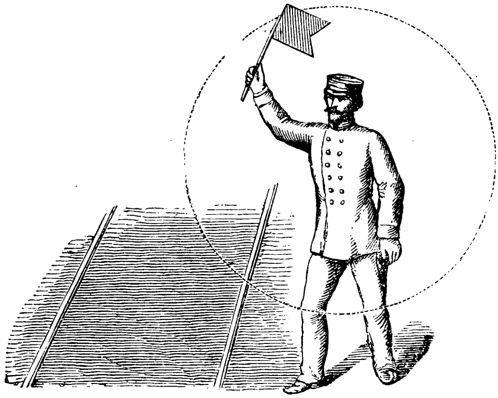


FIG. 23.

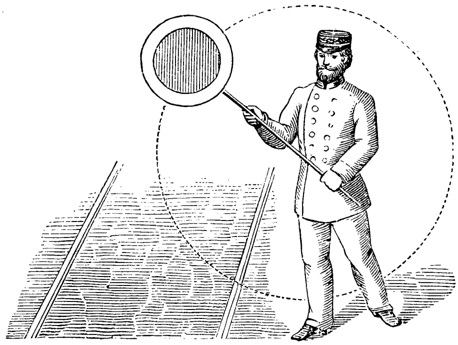


FIG. 24.

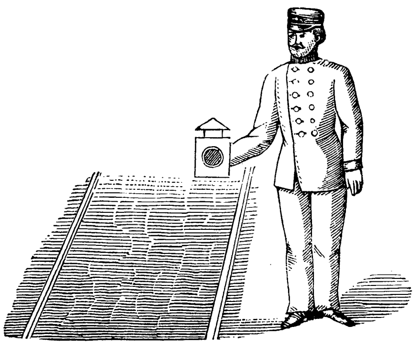


FIG. 25.

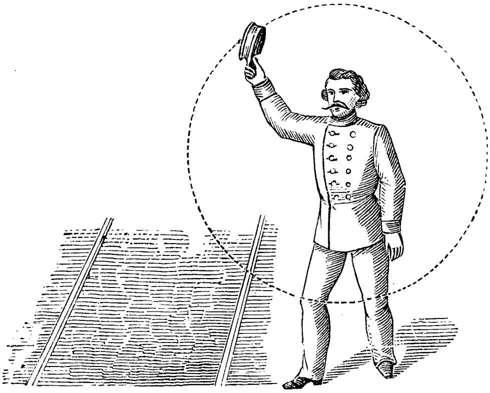
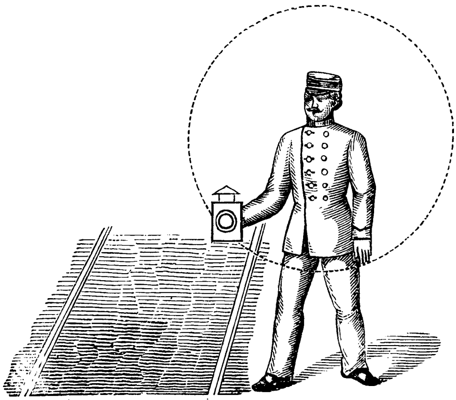


FIG. 26.



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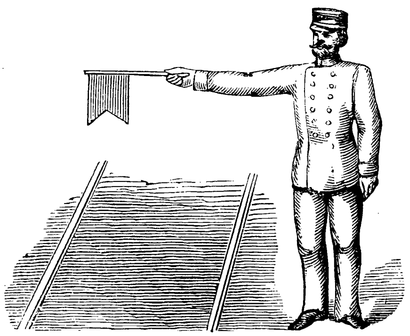

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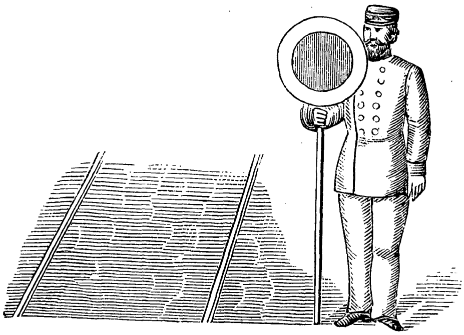

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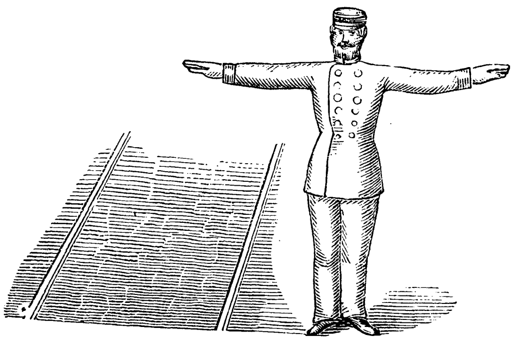

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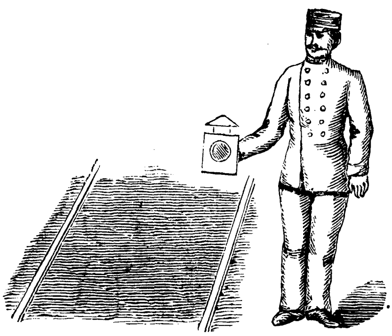

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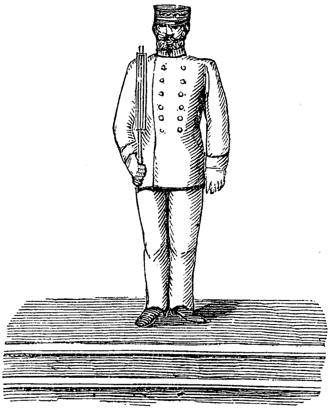

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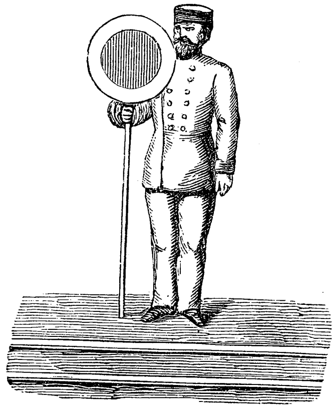

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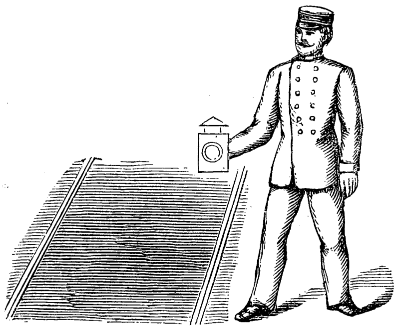

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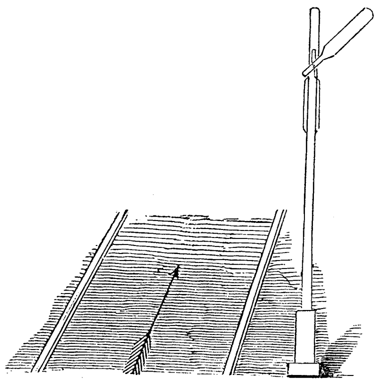

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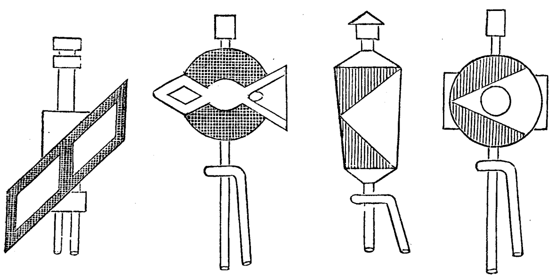

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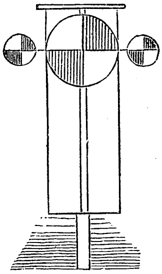
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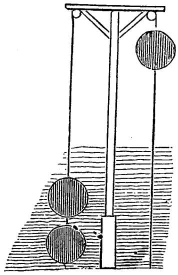
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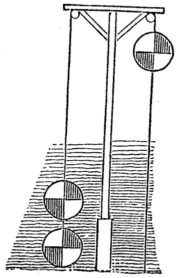
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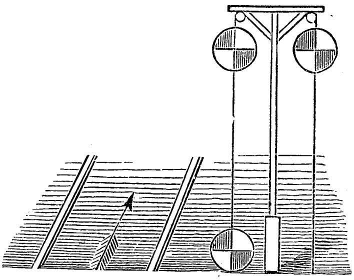
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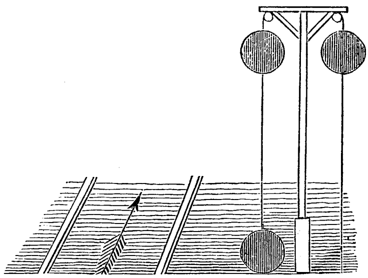
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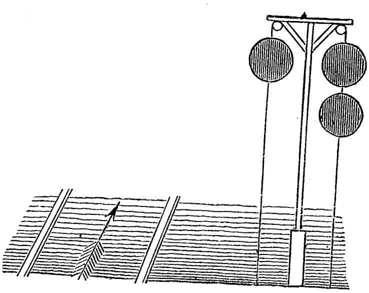
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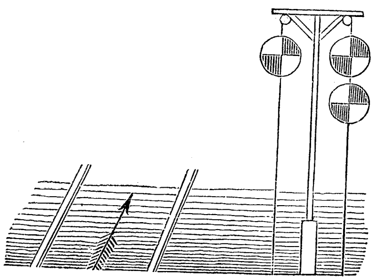
FIG. 43.

INDEX.

A.

CONSTRUCTION OF DWELLINGS IN VIENNA.

J. R. NIERNSEE.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON THE

CONSTRUCTION AND EMBELLISHMENT

OF

PRIVATE DWELLINGS IN VIENNA.

BY

JOHN R. NIERNSEE, F. A. I. A.,

MEMBER OF THE ARTISAN COMMISSION OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

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CHAPTER I.

HISTORICAL SKETCH OF THE VIENNA SYSTEM OF DWELLINGS.

VIENNA, ITS SIZE AND LOCATION; ORIGIN OF APARTMENT-HOUSES; SIZE; EXTENSION OF THE CITY IN 1858; ITS PREVIOUS SLOW GROWTH; ORIGIN OF THE ZINS OR RENTED HOUSE; ARRANGEMENT; DEVELOPMENT OF PRESENT SYSTEM; APARTMENT-HOUSES, THEIR ARRANGEMENT; EXAMPLES.

1. To fully elucidate the subject of this report on "private dwellings," we give a brief historical sketch, showing the origin of this class of dwellings, and the causes which gave them the peculiar and distinctive features of their present form, as habitations for the large majority of the people of this city—Vienna.

The capital of the Austrian Empire is situated in the vast valley called the March-field, on the banks of the Danube. It was known already as a Roman city in the second century, and was adopted by the Hapsburg family as their residence A. D. 1276. The city has remained in their possession to the present day. It now contains, in round numbers, 1,000,000 inhabitants, and is over twelve English miles in circumference. Up to the year 1859, the city proper was small, and was surrounded by high and formidable walls, encircled by a deep moat, over which twelve bridges gave access to the inner or old town, around which grew up gradually thirty-four new districts or suburbs.

2. The inner city was mostly occupied by the palaces of the nobility, and by large ancient buildings, subdivided and used for lodgings or so-called "apartment-houses." They were not generally (or were only imperfectly) suited to that purpose. The same plan was used, but in a more humble and cheaper way, and on a smaller scale, in the suburbs of later date.

3. Some conception of the magnitude of those old structures used as "apartment-houses" may be formed from the fact that several of them, which are still existing, and used for the same purpose, contain each from ten to twelve different large interior court-yards, and a much larger number of staircases. Such are the so-called "Burger Hospital," in the inner city, near the new opera-house, the Drahtner Court, and the Count von Stahremberg mansion, in one of the suburbs, said to contain each from 1,500 to 2,000 inhabitants. Many of these old buildings are from six to seven stories in height above, and generally two cellars in depth under ground.

4. Since the demolition of the old fortifications in 1858, the filling up

of the large trench and leveling of the glacis, large building-space has been gained, which has been extensively built upon already, and which is now adorned with numerous magnificent edifices and splendid palaces. The central part of the old town, or city proper, which is of almost circular form, is surrounded by a wide street, called the Ringstrasse, a superb avenue, with wide sidewalks, rides and carriage drives, and traversed by street-railways. It is crossed at the north end by the Danube Canal, and on the west by a smaller stream, called the River Wien. Thus the demolition of the old wall and improvements connected therewith have incorporated the formerly outlying thirty-four suburbs, with the old town, into one city, the extreme outlines of which are still surrounded by a barrier and ditch, called the Lines. The new "Danube Regulations," begun in 1870, will furthermore add a very extensive tract in expansion of the city.

5. Prior to the enlargement of the city in 1858, the old dwelling-house or "zins-house" (house for rent) was only an aggregation of living-rooms, which were to be more or less separated or united, according to the wants or wishes of the tenant, and which had to be occupied whether right or wrong, suitable or otherwise, on account of the scarcity of dwellings in the old metropolis. For, while the population in the fifty years between 1800 and 1850 had more than doubled, the number of houses increased only by 2,000 in the same period. Before the great political changes of 1848, and the subsequent enlargement of the city in 1858, the want of space, great cost of building-sites, and particularly the old oppressive building-laws, requiring heavy arched cellar and ground floors, (before the rolled-iron beams and light arches were invented,) and, consequently, walls three and four feet in thickness, and compelling many other expensive constructions, it was almost impossible, even for business-men of good means, to rent, in any eligible neighborhood in the city, a house embracing more than three or four apartments, inclusive of kitchen.

6. For this reason, many badly-planned and ill-ventilated apartment-houses were erected, consisting of very small suits of rooms, arranged to sublet rooms to secondary tenants, to the great inconvenience of all. Thus were developed those rows of apartment-houses, (or dwellings for rent,) called "zins-houses," in the former suburbs of Vienna, of which Plate I shows the type, four, five, and even six stories in height, containing several separate tenements on each floor, each consisting of only three or four apartments, viz, a kitchen, one or sometimes two rooms, and a cabinet, (*kammer*,) which latter is always understood to be a small room with *only one window*. Even the latter room was so arranged, with a separate entrance from the kitchen, so as to be able to sublet it. A stair and corridor, always of fire-proof construction, give access to all the rooms. Better and larger buildings were subsequently arranged, with more rooms and conveniences, such as the addition of a servant's room in connection with the kitchen, an extra chamber, and sometimes an

"ante-room" and pantry, better arranged and more completely detached water-closets, &c. (See Plates II, (A–H,) and III, (A–D.)

7. The construction and contrivance of the generally contracted kitchen, particularly where a cook has also to find her sleeping-place in it, are really ingenious. A large portion, generally the back half of the kitchen, is devoted to the cooking, and often the stand-up or covered bedstead is divided off by a beam or girder lying across from wall to wall (for all the partitions are of brick) about the height of the head, say five and a half to six feet at most, above the floor, from which beam the brick arching is turned up toward the ceiling, and the large open mouth of the chimney in the back, or so-called middle, wall of the house; by forming thus, as it were, a mantle or large hood over the range, and the space within the cross or hearth beam is in the shape of the large kitchen-chimney of ancient castles and monasteries, an excellent draught is created both for the fire and for carrying off effectually all the odor of cooking. Their compact brick and plastered kitchen-ranges, with brass-bound curbs, and with no iron but the top plates, glazed earthen vessels for cooking, small stew-holes and ovens, all wonderfully neat, compact, and effective, are well contrived and worthy of study and imitation. When the cooking is done, the fire is never kept up a minute longer than absolutely necessary. A curtain, sliding on rings on a rod fastened to the hearth-beam, is drawn close. No sign or smell indicate the presence of the cooking-apparatus. The floor is generally laid with hard stone or encaustic tiles.

8. After 1858, the enlargement of the city space, and the altered political and social conditions of the citizens, brought about by the changes of 1848, gave building matters a new impulse and direction. The desire of the inhabitants for a better system in the arrangements of their dwellings, more compatible with their new views and wants, was ably seconded by several of their most eminent architects and master-builders, who devised and perfected such plans as made, finally, the living in rented apartments not only bearable, but pleasant and convenient, nay, made it absolutely comfortable and even luxurious, more economical, and devoid of much care and responsibility, as compared with living in entire and separate houses after our American fashion.

9. From this time dates the present complete system of apartment-houses of the various classes, and of more or less pretension, which constitute virtually the "private dwellings" of at least nine-tenths of the citizens of Vienna. Only the highest and wealthiest of the nobility, perhaps a score of millionaires, and the members of the imperial family, some wealthy bankers, and a few merchants occupy entire houses (here called palaces) by themselves. The eminent architects, Vandernüll and Siccardsburg, are said to have been the promoters, if not virtually the founders, of the present perfected system of apartment-houses. The requirements of an average-sized tenement under this system are an isolation from the common stair and corridor of the house by means of

an inclosed vestibule, or ante-room, giving access to the kitchen, and to at least one living-room. This should also afford access to the water-closet and pantry, all well-lighted and ventilated. In connection with the kitchen should be a servants' room, which ought to communicate with a chamber and nursery.

Plate IV represents the details of the ground and first floor of such an apartment-house, which, at the same time, forms a *group-building* belonging to four different owners, fronting on three streets, and facing on the main street 132 feet, with a depth of 174 feet on the side streets, with four separate entrances or carriage-ways, each 8½ feet in width, and leading to a very ornate grand common court-yard of 64 feet in length, and 38 feet in width. There are, besides, several smaller courts one for the use of each building, with a large fire-proof stair-case of 6 feet width of steps for each. The general arrangement and uses of each set of apartments will be seen in Plate V, (A–H.)

The ground-floor is occupied by offices and reception-rooms, the first floor by the living-rooms of the owners, and the third floor *only* by one separate tenant.

10. Before proceeding further with the description of the development of the *dwelling*, from its simplest to its most expanded and ornate form, we must take note of a peculiar local feature in the configuration of the main business streets of the city, in regard to their influence on the arrangements and construction of these buildings. Where broad main, streets lead from the circumference of the outer districts to the inner, or old city, the ground-floor of a dwelling on such a street is generally devoted to business-purposes, while in the less frequented side streets that floor is used for inferior lodgings, work-rooms, or shops.

11. The first floor above the ground (*ebener erde*—even with the ground) is called the ground-floor, or *parterre*, and what with us in America is called the second floor is with them the first floor, also called "*belle etage*," or "best floor." In many of the buildings of greater pretensions, a lower or intermediate story interposes between the ground and principal floors, and is here called a "*mezzanine*," an Italian term, corresponding in meaning to the French "*entresol*." This is generally used for domestics' lodgings and other purposes. The section immediately below the ground-floor is called "*souterrain*," or sub-cellar, and in it are generally the stables of the larger and more pretentious town-houses when devised as apartment-houses. It is accessible by convenient inclined planes, called "*rampe*," for the descent of the horses. Below this sub-cellar is frequently the cellar proper, for fuel, wines, &c. The place directly under the roof, with us called *garret*, is never allowed to be inhabited, in accordance with the existing building-laws.

12. The reader of this description of the "apartment-house," as the principal *dwelling*-place of the population of Vienna, must not confound it with what is familiarly known to us under the name of *tenement-houses*. The so-called apartment-house in Vienna is the house of the majority of

every class and condition, from the poor student or clerk to the tradesman and merchant, or to the highest nobility of talent, industry, wealth, or title. As an enthusiastic admirer of the system expressed himself, perhaps sarcastically, "No city in the world is better calculated for life in lodgings than Vienna, as all the necessaries are abundantly provided out of doors."

13. A fine example of a first-class apartment-house is represented by Plate VI, in which A represents the first floor and B the plan for the second and third floors. This building has street-lights only from two sides; the remainder is lighted from the courts. It shows an example of a dwelling in which the ground-floor is occupied by offices, stables, carriage-houses. The first or principal floor is wholly occupied by the owner of the building. It has a semicircular private stairway and a large main stairway which leads to the upper stories. The accommodations in the owner's dwelling, on the first floor, are very extensive, consisting of culinary and domestics' apartments, pantries, and store-houses, four water-closets, bath and dressing rooms, ante-room, teachers' and governess's rooms, nursery, library, boudoir, reception and card rooms, parlors, dining-room, and billiard-room. The second and third floors are each arranged in three convenient sets of apartments, containing, respectively, four, twelve, and eight rooms per set. This building is sometimes called a "palais," the word, nevertheless, not meaning strictly palace; it is a sort of diminutive of the latter term, which they only apply to such buildings (whatever may be their size) as are not strictly "apartment-houses," but are occupied only by the owner, his servants, and immediate dependents and employés.

Another example of these first-class apartment-houses is the so-called "palais" of the banker Epstein, Plate VII, showing the first floor. This splendid dwelling, built on the Court Ring in 1871, contains in *souterrain* (sub-cellar) the stables of the owner, accommodating eight horses, and also for the tenant on the second floor, with room for six horses, with the necessary feed and harness rooms, an ice-cellar and ample cellarage for fuel for all, and heating-apparatus for the larger rooms of the owner. On the *parterre*, or ground-floor, are located the offices and counting-rooms of the owner, carriage-house and *concierges* lodging, and a spacious decorated entrance-drive to the court-yard. On the first, or principal, floor are arranged the artistically-decorated living-rooms of the proprietor, with renaissance ceilings in stucco, fresco-painting, and gilding by skilled artists, walls with scagliola marbles, costly and tasteful walnut wainscotings and tapestries. The walls of the card-room are decorated with fine landscapes. In the lettering of the plan, A designates the court-yard; B, small open courts for light and ventilation of private stairs, corridors, and water-closets; C, the rectangular grand stairway, which leads also to the second floor, and is highly decorated with variegated marble, scagliolas, and statuary; D, a second semicircular fire-proof stair, which leads to the second and third floors, oc-

cupied by one tenant on the second, and arranged for three sets of apartments on the third floor. A small oval private staircase, E, leads to the upper stories, and is principally used by the servants. The owner's lodging contains, No. 1, ante-room; No. 2, teachers' room; No. 3, sons' room; No. 4, library; No. 5, work-room or study of the owner; No. 6, card-room; No. 7, dining-room; No. 8, music or ball room; No. 9, reception-room; No. 10, boudoir; No. 11, family chamber; No. 12, nursery; No. 13, daughters' room; No. 14, governess's room; No. 15, baths; No. 16, wardrobe; No. 17, waiting-maid's room; No. 18, kitchen; No. 19, pantry; No. 20, waiting-room; Nos. 21 and 22, closets; No. 23, winter-garden or conservatory; and besides, three water-closets. The servants' rooms are located in the entresol, or mezzanine.

14. *Building-group.*—It is often the case that quite a number of otherwise distinct dwellings, owned by different parties, are grouped together in their external architectural features, under one general design and style, for the sake of producing a grand effect by a combination of masses, which could not be as well accomplished otherwise. This is an effectual, and also an economical, means of attaining this effect, as well as of combining the otherwise small courts of each into one or more larger court-yards. It is better for light and ventilation, for, as a rule, only the inferior rooms, corridors, kitchens, &c., are located on those courts, unless the latter are very large and ornamental.

15. One of the grandest examples of this kind is presented by the building, Plate VIII, called "Henry's Court," on the Opera Ring. It consists virtually of three separate apartment-houses, combined under one design and façade. The buildings occupy a whole square of 310 feet length, and 150 feet in depth, bounded by four streets. The central building forms a projection on the plan, and is one story higher than the side or end buildings, and rises like a tower above the rest. The façade of the parterre and mezzanine are treated as a grand rustic sub-base or dado. The windows of the first and second floors are coupled in connecting groups, and the third story is treated with pilastered windows and intermediate connecting panels, painted in rich frescos on gold ground. Architectural decorations and statues are executed in terra-cotta with excellent taste. The whole forms a magnificent apartment-dwelling.

Plate IX represents the plan of the principal or first floor of another such group of buildings, on a very irregularly-shaped piece of ground, two sides and a corner facing on streets. It was built by the Union Building Association. The effective façade is treated in the French renaissance style. The ground-floor contains stores and restaurants; the four upper stories are each divided into four large and convenient apartment-lodgings. This building has just been finished.

CHAPTER II.

CONSTRUCTION AND EMBELLISHMENT OF DWELLINGS.

VIENNESE BUILDING-MATERIALS; STONE BUILDINGS RARE, BRICK BUILDINGS COMMON; METHOD OF PLASTERING CEILINGS; QUALITY OF LIMES AND CEMENTS; BUILDING-LAWS; FLOORS, CEILINGS, AND DETAILS; PRECAUTIONS AGAINST FIRE; SELF-CENTERING ARCHES.

16. Having thus fully illustrated the origin and development of the present system of dwellings in Vienna, both in its simplest and most expanded and ornate design, we will next examine the methods of construction and embellishment. The materials used in construction first deserve consideration; Vienna is extraordinarily well favored in regard to the abundance in the vicinity of a variety, and of superior qualities, and also by extensive land and water communications with the neighboring provinces. Of ordinary hard quarry-stones for foundations there is an excellent and abundant supply in the vicinity. Of superior sandstones, soft and of middling and of hardest qualities, generally of a light-yellow or pale-buff color, much resembling the French Caen stone, there are sixteen different varieties used here. The Vienna and Emperor's sandstone, the Magarieth and Loretto are favorites, and are extensively used for external window and door dressings, ashlar facings of walls, and ornamental cut-stone work in general. The harder kinds are generally used for steps and platforms of interior stairs, corridors, and bases of the buildings. For monumental works, columns, &c., granite as well as marbles from Karst, Untersberg, Salzburg, and Silesia, and variegated Hungarian and Bohemian marbles are used.

17. Solid sandstone constructions, except for Gothic churches, are, however, rarely used. Only *facings* of stone for public buildings, and the more costly palaces and dwellings, are employed. Of entire marble façades there are very few in Vienna. The favorite and almost universal building-material is brick of superior quality and hardness, which is produced in immense quantities in the immediate surroundings of the city. Externally the walls are covered with a superior quality of mortar, made of the celebrated Kuffstein or other hydraulic cement mixed with sharp river-sand. This mortar acquires fully the hardness of the sandstones, and is not only used in plain surfaces, but all their cornices, window, door, and other architectural decorations and features, are worked out with surprising accuracy, strength, and beauty by their skilled masons in that material. To illustrate this use of cement a view, taken from a photograph, is annexed of the front of a new dwelling

on the Ring street, (Plate X,) the whole of which is done in this hydraulic mortar. The more florid ornaments, capitals of columns and pilasters, &c., are cast in cement and terra-cotta, and the whole is colored a pleasant and uniform light-buff color, resembling stone. The masons build both the stone and brick walls, turn all the arches, and do all this external plastering or cement stucco and coloring.

18. The interior stucco-work, or plastering of walls and ceiling, is done by the regular plasterer. In this connection, one peculiarity in the mode of plastering their ceilings deserves special notice. Their ceilings, and also the floor-joists of their solid timber floors, where the beams lie close to each other, side by side, do not admit of lathing for plastering as in our dwellings.

They adopt the following method: Stout lathing-nails with rather large flat heads are driven first partially (say half way) into the ceiling-joists at distances of seven, eight, or nine inches apart, as first, second, or third quality work may be desired, forming regular squares. The uniform spacing of the nails is quickly and accurately done by marks or notches cut on the handles of the small hatchets with which they drive them, and they range them by the eye. On these nails, just above the heads, stout copper wire (also of a size according to the quality of the work) is loosely stretched by giving the wire one turn around each, and in a direction *crosswise* of the ceiling-beams, thus forming a loose wire netting hanging down from the ceiling from three-fourths of an inch to one inch. Instead of laths they use reeds or small canes. These reeds come in bundles of about twelve to fifteen inches in diameter, and six to seven feet in length; none of the reeds must exceed three-quarters of an inch in diameter at the thickest end. The extremely thin ends are cut off, so as to have none less than one-quarter inch in thickness at the smallest end. They are introduced between the wires, at such distances from each other as to afford a proper key between them for mortar. They are also reversed between alternate squares, so as to have the ends of one pushed in and overlapped between the thicker ends of the other square, thus equalizing the thickness. After this the nails are driven moderately well *home*, without forcing the wires into the reeds, so as to injuriously bruise or cut them. Next, rich tenacious plastering mortar is *flung on them* with a scoop-trowel and then finished in two or three coat work, as with us, or as the nature or finish of the work required. The interstices between the faces of the reeds and their round shape form a frequent and excellent key or holdfast for the mortar. The reeds are also seasoned before being used.

19. The sand used for building, both pit and river sand, is of superior quality, as also are their common and hydraulic limes and cements. The bricks of all manufacturers are of the standard size of 11 inches in length, $5\frac{1}{4}$ inches in width, and $2\frac{1}{2}$ inches in thickness. Of woods, both for building and ornamental purposes, they have an abundant supply from the forests of the various provinces. They are generally

transported by water. The hard woods of Hungary, such as oak, ash, and walnut, are particularly rich and valuable. Iron has been brought into use in the construction of buildings of late years, and is employed principally for girders and beams. Some roofs and stairs of public buildings, conservatories, and many bridges, both on the arch and suspension principles, are built in iron, but buildings entirely of iron have not been introduced here as yet, although they have an abundance of superior quality throughout the empire.

20. Besides the excellent quality of the limes and sand they employ for their mortars, their treatment in mixing and using them is worthy of notice and of imitation. Their first proceeding toward the erection of a new building is the digging of large pits, say eight to ten feet square, and of about the same depth. If the ground should be too loose or porous, they surround or case them with light brick walls.

The lime is carefully slaked in a large trough supplied with a small gate and a tolerably fine-meshed wire screen at one end, immediately above the lime-pit, and as each trough-full is thoroughly slaked and agitated, and brought to a uniform degree of fluidity, it is drawn off into the lime-pit. The operation is repeated until, one after the other, these pits are filled. The number of lime-pits thus filled, and the quantity prepared, is generally such as to furnish from four to six months' supply for the building; and as one is emptied it is freshly filled until its turn, at the proper interval of time, comes again for use. This fluid slaked lime, originally of the consistency of thick cream or molasses, will cool off, settle, and consolidate, in the course of several weeks, to about the consistency of soft butter or paste, and the water separating from it during its partial consolidation, and standing to the depth of several inches on top, will keep it good for months, or even a year or more, in the proper pasty consistency, ready to be mixed with the sand when required to be used for making into mortar. If the lime remains an unusually long time in the pit, and absorbs all its own water, more is poured on to keep it in its pasty condition; for when it once hardens, it is no more fit for use than plaster of Paris after it has set. When the lime is wanted for mixing into mortar, it is lifted out of the pit by a long-handled broad hoe and put into the mortar-mixing trough with the proper measured proportion of sand and of water to thoroughly reduce it to a semi-fluid condition. It is carried in round flat tubs or buckets to the workmen, who are supplied with small deep troughs holding about the quantity of a good-sized barrel. The mortar is used in so fluid a state (almost what we here technically call "grout") that it could not be taken up on our ordinary trowel. There the masons use large concave trowels, shaped somewhat like sugar-scoops. A superior and skilled laborer, called a mortar-mixer, is employed in the preparation of the mortar.

21. This system of slaking and cleaning the lime by running it through a wire sieve, and mixing it thoroughly with a proper proportion of sharp

clean sand, and then applying it in this semi-fluid state, has much to do with the superior quality of their mortar, and consequently with the strength of their walls and the durability of their exterior coating. Their bricks being rough, well bedded, and rubbed or hammered down into this soft mortar, filling up all the vertical interior joints of the brick-work, it gives all the strength and solidity of "grouted" walls, while at the same time the mason is not allowed to bring the mortar either on the bed or the vertical joint, nearer than within half an inch of the face of the wall. This is required to give a proper hold or *key* to the mortar when both the exterior and interior rough-cast plaster coating is put on in the finishing of the building. Some buildings, as the new arsenal, some railway-stations, and a few churches, are finished with face brick. Sometimes they are of various colors, such as pale red, gray, or buff; or they are dark, and dressed off with terra-cotta panels and other embellishments, as sandstone window-trimmings, bands, and bases.

22. The construction of dwellings is in many respects so guarded, and regulated by numerous regulations and strict building-laws, that the latter give a certain uniformity to the former, and in describing their construction we almost quote the law. Thus they require that the main walls, front and rear, should not be less than 18 inches for the last or topmost story of the building, and as now no building is permitted to be more than four stories in height above the ground floor, or thirteen fathoms, 78 feet, from the top of the cornice to the sidewalk, they permit the walls for two stories down to be made the same thickness, while they are to increase in thickness by the width of one brick, six inches, and below that as follows: From the top down, 18 inches for fourth and third stories; 2 feet for second and first floors; 2½ feet for the ground floor, and at least 3 feet thickness, as prescribed by law, for the cellar. They always have also what is called a middle wall, in which the chimney-flues are located, and as the floor-joists are to lie six inches on the wall on each side of this wall, and as the law prescribes that not less than one foot of brick-work shall intervene between the ends of these joists, we have two feet in thickness, except the upper story, which may be eighteen inches. All party-walls must be at least one foot in thickness for each party. All division-walls between different apartment lodgings in the same house must be one brick, or twelve inches; interior partitions one-half brick, or six inches thick. While building, the front must be temporarily fenced in for six feet in width outside the building-line for safety of passers-by.

23. Cellars under ground, containing stables and feed-rooms or workshops, must have a brick arched ceiling. Others may have solid timber joists or beams, but always 4 inches depth of pugging or earth-filling (generally of old plastering; old mortar-rubbish, screened, is used for that purpose) between the ceiling-joists and flooring. Their wooden floors or ceilings between the stories are generally of two kinds, either

of floor-joists standing on edge, like ours, but only 12 inches apart between centers, or for wide spans solid timber laid close together and connected by tree-nails, all with 4 inches depth of pugging between them and the flooring. The latter kind (solid timber) are always used in the story immediately under the roof, as that floor must be made fire-proof by being paved with brick laid in cement.

24. The stair-walls, when of brick, must run up to the roof-timbers, and the entrance from the stair to the roof-space must be secured by an iron door, set closely into stone jambs. The roof-space is only divided into what we call "lumber-rooms" for the various occupants of a house. No chamber or living-room is ever permitted there under any circumstances. Each chimney-flue must have a well-secured double iron door, opening under the roof 3 feet above the floor, for cleaning. Each roof over 45 feet in length must have a 6-inch fire partition-wall, with an iron door for access from one space to another; and the fire-walls must run at least 6 inches above the roof-timber. The latter are not permitted to connect with each other or rest upon this fire division-wall. Each house *must* be supplied with water, either by means of a well in the court-yard or by public water-works. No sub-cellar or sunk basement can be inhabited unless its ceiling is at least 4½ feet above the sidewalk. No ground or parterre floor shall be less than 6 inches above the pavement. All stairs and connecting corridors and halls giving access to the various tenements must be fire-proof, either of stone, brick, or iron. Main stairs are not to be less than 3½ to 4 feet in width, and the steps must not be less than 11 inches in width or more than 6 inches in height. Stairs opening on a well-hole must have a guard-railing of at least 3 feet in height, and *the top rail must be guarded against accidents from children sliding down on them by ornamental knobs or projections placed every 3 feet apart.* This is a simple and very effective safeguard against some of those dreadful accidents which so frequently happen. The height of any story shall not be less than 9 feet in the clear.

25. The division-wall between chimney-flues and any wood-work shall not be less than half a brick, or six inches; and, in addition, a brick tile on edge shall be laid between the chimney-wall and the wood-work, so as to cover the joints between the brick. The flues must be well plastered, both inside and outside. Chimney-flues are of two kinds: either the wide flue for the passage of chimney-sweeps, 18 inches square, or the narrow or Russian flue, of not less than six inches square for one fire, or six by nine inches for two fires. Flues should be as nearly as possible perpendicular, but should in no case be drawn more than at an angle of sixty degrees with the horizon. No wooden cornices are allowed. They must be either of stone or brick, or of cast or galvanized iron. Roofs must be covered with tiles, slate, or metal, and snow-boards must be provided. Wooden subpartitions of rooms may be used, if well plastered on both sides, but they are only used in very inferior buildings, and are generally half a brick or six inches in thickness, resting

on a rolled-iron beam where there is no corresponding support below. There should be one water-closet for each tenement, of not less than two feet nine inches in width, with good light and ventilation, and having a large ventilating-pipe carried up through the roof. Where public sewers pass through the streets, a private sewer of brick, oval in shape, of at least two feet in width and three and a half feet in height, must be laid in cement-mortar and connect with the former. It should also be ventilated by a large pipe passing up above the roof.

26. No outside steps should project beyond the building-line; and no projections of bases or of the fronts for architectural features or shop-windows of stores should exceed nine inches. Balconies and bay or oriel windows should never project more than four feet, nor exceed the length of one pier and a window's width, nor be less than nine feet above ground, and nine feet in distance from a neighbor's house. They should not be placed in a street of less than forty-eight feet in width. A special permit is required for them. The kitchen-hearth should be of brick or stone for at least 2 feet in width outside the fire-place. Corridors should be not less than 4 feet in width, and made of stone or arched in brick. The windows are always furnished with double sashes, and are generally made in the French-casement style, opening like folding doors at the center. The outer ones in the old style open outward, but in consequence of the occurrence of many accidents, the new law obliges them to be made to open inward, like the inner pair; and this occasioning some inconvenience in the fastening back and in their use, the American sash or hoisting window has lately come into use. Still they are used double, saving a large amount of fuel in winter and dust and heat in summer.* The doors are generally double or folding doors, opening at the center, one half generally fastened and the other free for ordinary use. They are very convenient, and project thus much less into the room. In large houses with very thick walls, the half wing of such a door is generally covered by the thickness of the wall. The kitchen floors are often completely tiled with stone, marble, or encaustic tiles. The floors of the best rooms in most houses, both old and new, are laid with parquetry square tablets of hard variegated wood, such as oak, ash, walnut, or mahogany. They are sometimes still further enriched by inlaying with other costly woods. They are tongued and grooved together, and laid on a soft pine or blind floor. They are waxed and polished frequently and quickly by regular polishers, who keep these floors in order, receiving pay by the year.

27. Earthenware or porcelain stoves are invariably used for heating apartments. The fire-door or heating-place for the best rooms generally opens upon some outside corridor, passage, kitchen, or inferior room. The stoves are frequently set diagonally across a corner of the room, and thus do not take up much space, large as they are. They are frequently of the size of a book-case, and much higher than the modern ones. They are generally ornate, and are sometimes of very rich and

* In summer, the outer windows are frequently unshipped and stored.

artistically-decorated patterns. They certainly give out a very pleasant and uniform warmth, and when once the fire is made it lasts through the day and late into the night, having all the uniformity of a bake-oven. Indeed these stoves somewhat resemble the oven, as inside the outer or ornamental shell there is a heavy lining of brick and clay. This is protected by a grating against injury from careless handling of the fuel. Through this structure the flues wind around with many turns until the smoke, before reaching the chimney, has parted with all its available heat. The heat is retained for a great length of time by the brick and earthenware of the structure. Thus there is neither the scorching heat of an iron stove nor the sudden fluctuations and extravagant waste of an open fire-place; and, where fuel is as costly as in Vienna, these stoves are valuable for their economy.

28. Before commencing a building, a permit must be obtained by placing a copy of the plans, sections, and elevations in the hands of the municipal building-commissioner, to be approved and signed by him. After these plans are examined and approved as in conformity with the existing building-laws, no deviations are allowed without special notice to the proper authorities. The building and the materials used are constantly and strictly inspected by the inspector of buildings, and an *injunction* is quickly served if bad material is employed, the plan altered, or any building-law infringed. No newly-finished building can be occupied until inspected and approved by the proper authorities as of safe and proper construction, as well as perfectly dry and as complying with all sanitary regulations. In matters of taste in the external decoration or design of a front or façade of a new building the government retains supervising power. Elevations are to accompany the plans, and, although in regard to architectural style there are no positive regulations, yet the proper authorities suppress or modify a positively ugly exterior, at least in so far as it would offend public taste.

29. This report on the construction of the dwellings of Vienna cannot be more appropriately closed than by a brief description of two kinds of what may be termed self-supporting brick arches, which are constructed in Vienna by the skilled masons *without the use of centering or any temporary supports during their construction.* They are only used in Austria, and they show not only the great skill and dexterity of these masons, but such a mechanical knowledge applied to construction as is nowhere else applied to the same purpose. This construction of arching self-sustained during construction no doubt had its origin years ago under the old building-laws, which required all of the apartments of a ground-floor or parterre to be arched. As that floor contains generally not only lodging-rooms, but offices and fine stores, the desire naturally arose to produce as light-looking, flat, and pleasing an arch as could be safely constructed before iron beams and girders came into use, avoiding the heavy and clumsy-looking barrel and gothic arches for low-pitched ceilings, as well as the great expense of centering during their

construction. There are two kinds of these so-called "*Platzel-gewölbe*"—*flat self-sustaining crown-arches.* The *self-sustaining* feature consists in its power of supporting itself during construction without centering. One of these arches is called the "Welsh," and the other the "Bohemian." Why *Welsh* we have not been able to ascertain, but the "Bohemian" arch, we have been informed, originated in the kingdom, now the province, of Bohemia, and was originally designed and introduced by the very skillful masons of that country, who still preserve their peculiarities of practice, both in Prague and in Vienna.

Front and rear walls being constructed, and the building in the rough entirely put up and roofed in, cross-girder arches, (called *gurten*,) really brick girders in the place of the present iron ones, are thrown across the rooms to be arched. These cross-girder arches are generally two bricks in width, and one and a half to two bricks in height at the center. The footings or abutments are always carried up with the construction of the regular walls until they project one and a half bricks beyond the inside face of the walls. These cross-gider-arches are afterward completed on a regnlar centering of wood with a groove of about 1½ inches in depth on their sides for the support between three of these flat-crown-arches. The same depth of curved groove is also cut in the front and rear walls (following the shape of the curve of the arch) while constructing. For the "*Welsh arch*," the girder-arches are generally placed at the center of each pier between two windows, being from 10 to 12 feet apart. The Welsh arch is never used over that width, but may be of the full length required by the depth of the room, although not usually over 18 to 22 feet in length. It is a favorite arch for halls and entrance-passages not exceeding that width. For the "Bohemian" arch the girder-arches are generally placed at every second pier of a room, say 16 or 18 to 20 feet apart, corresponding to the width, or rather to the depth, of the room. In all cases these arches are used in square apartments, or as nearly square as they can be arranged. Through the girder-arches run strong lock or anchor irons, to guard against the pressure on the sustaining-walls. The "Welsh" arch is segmental in all directions; the "Bohemian" is a spandrel arch, or dome, growing out of a square apartment. The courses are laid in the form of circular arcs, commenced in the corners, and curved and declining toward them. In either of the two methods, every course of the arch laid in this way without a centering is really complete and self-sustaining, very nearly as much so as if the whole of the vault were finshed and finally closed. The spandrels, particularly at the commencement of the Bohemian arch, are filled up solid for about one-third or one-fourth of the size of the vault. Both kinds are closed with half a brick or six inches thickness at the crown or center. The sole guide for the mason is the curve and nosing-line on the wall and girders, and a center-pole or other mark for height set up for the closing-point at the crown. The rest is all guided by the practiced eye of the workman.

The rise of the "Welsh arch" is generally one twenty-fourth the span. The "Bohemian arch" is also very flat at the crown as compared with a full center hemispherical dome. The Welsh arch is generally commenced by one mason at each end; the "Bohemian arch" by four masons, one in each corner, until the corners meet, and they are then completed by two, of whom one finally goes on top the yet incomplete arch and hands in the materials, while the other one, in the central hole below, attends to the setting and the eye-line of the courses. These men are so skilled and practiced in their trade that they hit by the mere use of the eye the true lines of the proper curves, as perfectly as if they were guided by a pattern or centering, and attain the closing-point at the crown with the utmost precision. Very rich mortar is used for these arches. Each brick of a whole course has to support itself, and skill in the mechanical manipulation consists in keeping every course to its proper and unbroken curve in every direction, and the courses at the proper dip to the plan, as well as in applying and bedding the brick in its proper place at once, by merely rubbing it as it were into its bed and into position, never *knocking* it up or down, or back and forth, by the use of a hammer, and thus breaking and disturbing its bond or adhesion to the mortar. As surely as this is done, or the curve-lines crippled, the whole will come down after six or eight courses more have been applied at the very point at which those disturbances occurred. These arches are often finished with different-colored bricks and with pointed joints without plastering, to show the beauty of their mechanical construction This is seen in many old buildings and in the corridors and entrances to the new arsenal and other "*rohbau*" ("unplastered or raw brick.") The plans and sections, Plate XI, will show the general principle of these ingeniously-constructed arches.

CHAPTER III.

ARCHITECTURAL FEATURES OF DWELLINGS.

Architectural development dating from the thirteenth century; Few examples remaining; Reigns of Joseph I and Charles VI; Effect of French wars; Impulses given in 1845 and 1857; Influence of the decree of 1857; Benefit of popular instruction; Skill of Viennese artisans; Beauty of new public buildings.

30. We cannot but admire the architecture and the embellishment of the new dwellings in Vienna, and give due credit to the architects of that city for the great advance which has been made during the past twenty-five or thirty years, particularly after the political changes of 1848, and since the new impulse was given to building after the demolition of the old fortifications and the enlargement of the city by the incorporation of the formerly outlying thirty-four suburbs with the central or old city. The history of the development of architecture in Vienna can only be traced back through its remaining monumental buildings as far as the thirteenth century. Of the Roman period there remain only two examples, and these are of the time in which the Gothic style had already obtained the preference. They are the western façade and turret of the Cathedral of St. Stephen's, and the nave and transepts of the Court Church of St. Michael's. More abundant are the remaining evidences of the building activity and architectural development of the Gothic style in the fourteenth century. The fine chapel of the Knights Templars of the Teutonic Order, the St. Augustine and Minorite churches, the nave and choir of St. Maria on the Stairs, the tower and choir of St. Michael's, and the apsidal choir and the incomparably beautiful tower of St. Stephen's are illustrations of styles which left their impress also on the private dwellings of that and the following period in the many steep roofs and gables, projecting oriels and turrets. Vienna is under small architectural obligation to the renaissance period, as, after the first siege of the city by the Turks, the whole energy of its people was expended in the improvement of its fortifications, and in more peaceful times taste in art was principally directed by the leading fraternities of religious orders, who, in their numerous new church buildings, restorations, and remodelings, often produced depressing combinations of styles, either too plain and sober or too showy and pretentious.

31. During the reigns of the Emperors Joseph I and Charles VI, another impulse to the building-arts was given by the examples of their luxury and splendor-loving nobles and the princes of the empire, led

by that great patron and admirer of the fine arts, the celebrated Prince Eugene of Savoy, who, by the erection and embellishment of palaces and public buildings, ably seconded by the talent of their celebrated architect, Fisher of Erbach, produced such fine works as the Charles and St. Peter's churches, the imperial summer palace at Schönbrun, the imperial winter riding-school, the court library, and many public offices. The palaces of Prince Engien, Trautson, Mannsfield, Auersberg, Lichtenstein, Schwarzenberg, Daunish, and Kinsky, the celebrated "Belvidere," and numerous other equally splendid buildings of the times. But the disastrous and long-continued French wars, from the very beginning of the nineteenth century to the fall of Napoleon, and the Hungarian, Italian, and other provincial troubles during the remainder of the first half of that century, and up to the final political changes in 1848, had retarded, nay paralyzed, all the industrial and fine arts in Austria, as well as in the rest of Continental Europe. The little of what was done during that period in domestic architecture was made up of bad imitations of debased Italian and servile copies of poor examples of French and Belgian style, derisively, but not not inaptly, designated by the fun-loving art critics of the times as "the curly wig and queue style," on account of the many unmeaning twists and turns of design, meant for ornaments, or introduced as so-called architectural features. The development of native talent and taste in arts were also much retarded during that period by the old system of bureaucracy, in which councillors, superannuated and incompetent directors, assumed the control of the public taste, affording no opportunity for the exercise of individual talents.

32. But after the displacement of this old depressing system, and after the call of the talented and eminent architects Vandernüll and Sicardsburg to the head of the Vienna Academy of Fine Arts in 1845, and with the enlargement of the city, and the establishment of schools of design and industrial and technical institutes, museums, art-schools, and by the energetic and praiseworthy exertion of the Engineers and Architects' Association, a new and well-directed impulse was given to the industrial arts, and that of architecture in particular. It was greatly aided by the imperial decree promulgated in October, 1857, directing the erection of great public works and improvements on a grand scale. The adoption of a wide Ring street around the inner city and improvements after the example of those of Paris were contemplated, the erection of two new museums for art and natural history collections, an exchange, new parliament houses, and a grand university building, a new "Rath-house," (city hall or hotel de ville,) an imperial theater, extensive improvements and additions to the imperial palace, a palace of justice, the new opera-house, and many others were projected, for which either select, local, or general competition among architects was invited and the designs of native artists received the principal premiums.

33. These were enterprises of such importance and magnitude, that

their execution, under favorable circumstances, within the next ten or twenty years, will mark this as a grand epoch in architecture. These works, which are put into the hands of the most worthy masters of their arts, will add a luster to the times, and magnificence and dignity to the great imperial city of Vienna. Several of these works have already been commenced; the designs and models for all of them are prepared and approved. The fondness for the Gothic style for ecclesiastical structures, which has been kept alive by grand old examples, and nourished by the continual repairs, and the finally thorough restoration of that splendid example, the southern tower, and western façade, and gable of the church of St. Stephens, was in later years followed by the erection of the rich Imperial Votive or Memorial Church, the new Lazarite, Elizabeth, and several other conspicuous church-structures in that style. The new Hotel de Ville is also now building in tastefully enriched Italian Gothic. In many of the proposed new public buildings above mentioned, the Italian renaissance style is predominant, while the French renaissance, or louvre style, is only shown in more isolated examples. Although for private dwellings a so-called general eclecticism exists here as elsewhere, there is an acknowledged predilection toward the vigorous and massive forms of the Italian renaissance in preference to the elaborate and lighter, but therefore probably more effete, French school of architecture.

All of the afore-mentioned causes of building impulse, seconded by these projected designs for the erection of public works, had also an invigorating and salutary influence on the architecture and embellishment of private dwellings, and one of the first and best examples of the successful reconciliation of tasteful architectural embellishments with the demands of practical wants and domestic usefulness is perhaps the new group of buildings called "Henry's Court," the apartment-houses already alluded to under the head of plans and constructions.

It has since that time become almost a point of honor with owners and architects to give the façades of new private dwellings more or less rich architectural embellishment. Although they may appear sometimes overdone, or in want of harmony with their frequently very economical and consequently meager internal finish and arrangements, yet we find many tasteful improvements among the lately erected dwellings. Since the renewed vigor of the many powerful and energetic building associations, who avail themselves of the best constructive and architectural talent of the country, a large number of palatial group or block buildings have been erected in that impressive Italian renaissance style, which gives to the new Ring street more the appearance of a street of palaces than of dwellings or apartment-houses. It is worthy of this great city, and its equal can rarely be found elsewhere. The great Italian cities, in their most flourishing periods of architectural grandeur, did not excel it. It is true that there may be, in some portions of the new Ring-street, a little too much uniformity, but this is well compensated by the large number of independent prominent private

dwellings and real palaces, such as those of Grand Dukes William and Ludwig Victor; of the Duke of Württemberg, now the Hotel Imperial; the palaces of Todesco, of Epstein, and of others; the Grand Hotel, the Hotel de France, Hotel Austria, Hotel Britannia, Hotel Metropole, Hotel Donau, and many more.

34. This gratifying advance, not only in the higher or so-called fine arts, such as architecture, painting, and sculpture, but in the industrial, technical, and mechanical arts and the trades connected therewith, within the last twenty-five or thirty years, is evidently mainly due to the establishment of many schools and educational institutions on a popular and economical scale, which are accessible to the humblest and poorest in the land for a small compensation, and often entirely free of charge, where all the elements of industrial knowledge, up to the highest branches of art-culture, are taught, and where the students are guided by the ablest professors, and their equally well qualified and competent assistants, and senior pupils—the latter of whom thus are not only teachers, but are executors of both public and private works. Thus the professors of the academy of fine arts furnish architectural designs. Professors of painting and sculpture, with their advanced pupils, execute work on public and private buildings of the empire, in addition to that done by regular practitioners of those arts.

But the artisans also, the masses engaged in mechanical occupations, have derived great benefit from being taught the art of drawing, not in its æsthetic sense only, as relating to forms of beauty, but in its technical sense, as enabling them to understand a drawing and to execute the work by the aid of the graphic plan alone; and they are taught in a practical manner so that they can execute these drawings themselves. They are thus able to dispense with the aid of models, which previously could be furnished only by a few cultivated experts. Now, every instructed and skilled artisan being competent to work from designs furnished him, or to furnish and execute them himself, with only occasional finishing-touches by the professors of the arts, these economical and tasteful architectural embellishments of dwellings have become the rule instead of the exception. We thus find the skilled mason and stucco-worker of the present day executing any design laid before him. And so with the house-painter, the carpenter, the cabinet-maker, the stone-cutter, the smith, the worker in any wood, mineral, or metal.

35. The Viennese thus get their architectural details well and economically executed by artisans, their designs furnished by competent architects, their sculpture done in any material in an artistic manner, and their house-painting either in plain and tasteful style by the skilled workman or in the highest style of art by numerous professional artists. Every one of their better class of dwellings is now designed and executed with a tasteful façade, and they are often enriched with considerable architectural embellishment, and sometimes with sculpture executed in stone, cements, or terra-cotta; entrance-halls, public or grand

stairways are furnished in the same manner, and often further enriched by scagliola or real and variegated marbles on the walls and frescoes on the ceilings. The walls and ceilings of the living and social rooms in their dwellings are always painted, at least in plain and tasteful water or encaustic colors, and are often embellished by works of artists in fresco and oil painting. They are thus enabled to produce their present and their best style of buildings by the combination of the three sister arts of architecture, painting, and sculpture, giving these buildings a harmonious and finished appearance, totally unattainable with the mere meager architectural composition and execution such as is seen in less favored countries. Drawing has been incorporated, for at least forty years past, as a useful and necessary branch of common education in the ordinary and high schools. It has been considered as indispensable in the school system as grammar, reading, and writing, and the masses have reaped as much benefit from the former as from the latter. The public taste has been vastly improved.

36. I cannot close this paper on the construction and embellishment of dwellings without expressing my admiration of that splendid product of architectural skill and artistic embellishment, the new opera-house, and of several of the lately erected new theaters, as well as of the grandeur and palatial magnificence of the new railway-stations. The "Staats-bahn" and New Southern stations especially are structures which, in their tasteful designs and richness of embellishment have not thus far been equaled in any part of the world.

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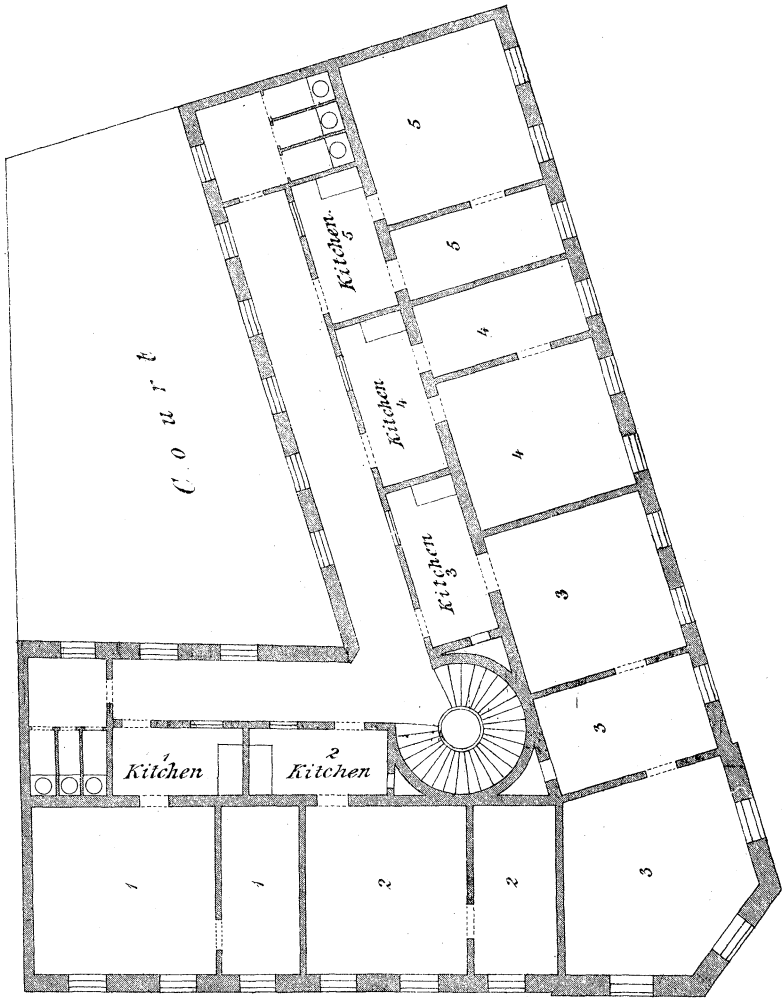
Plan of Principal Floor of small Apartment House, Vienna.



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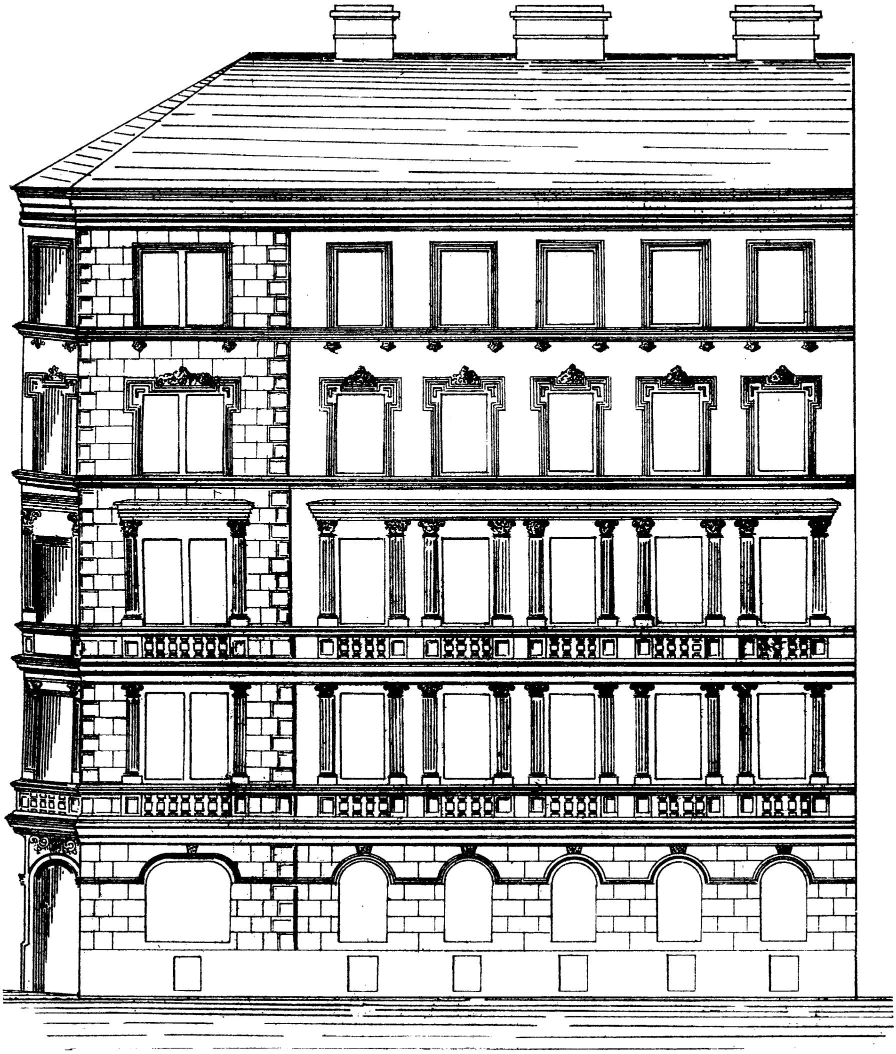
Apartment House in Vienna. Pl. II. (A.)



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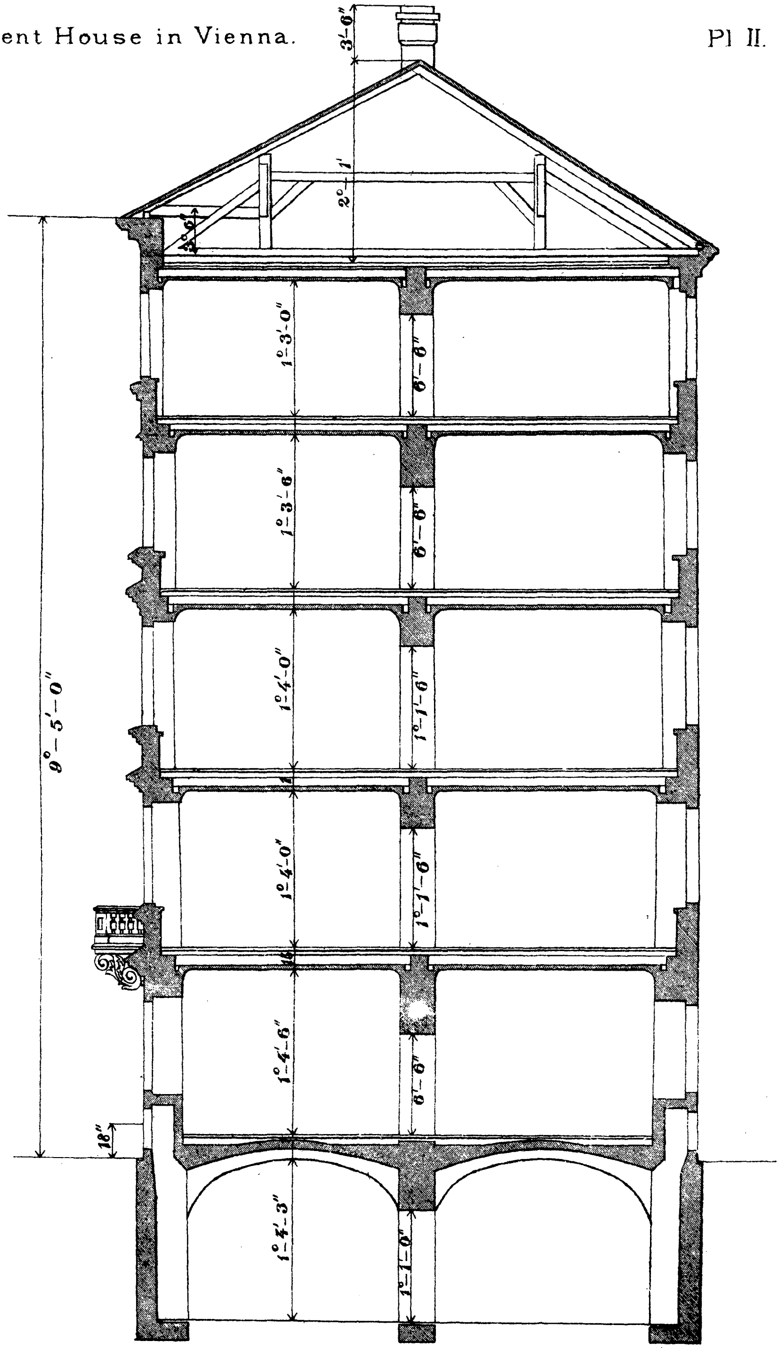
Apartment House in Vienna.

Pl II. (B.)



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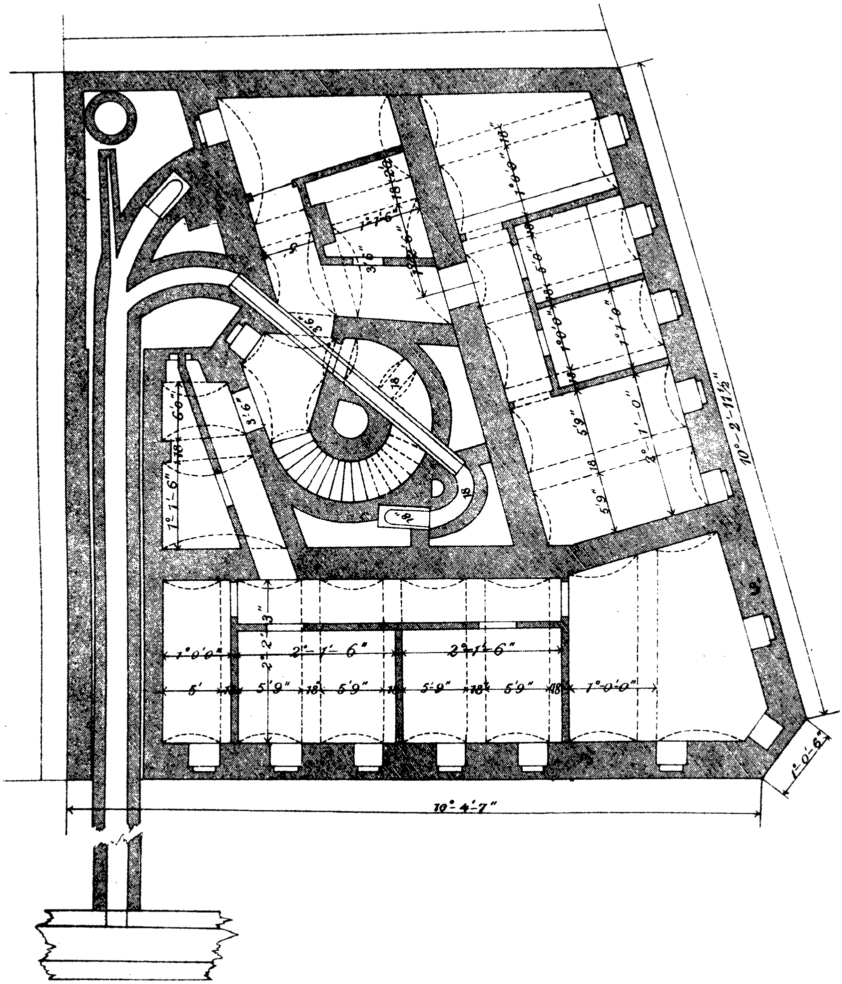

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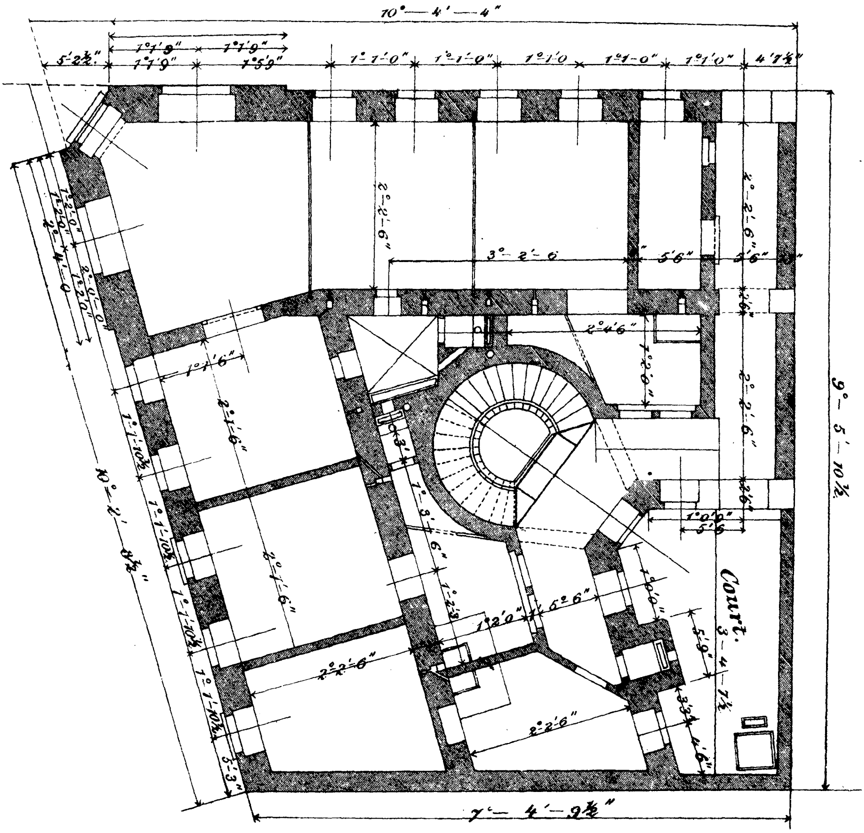
Apartment House in Vienna. Pl. II. (D.)



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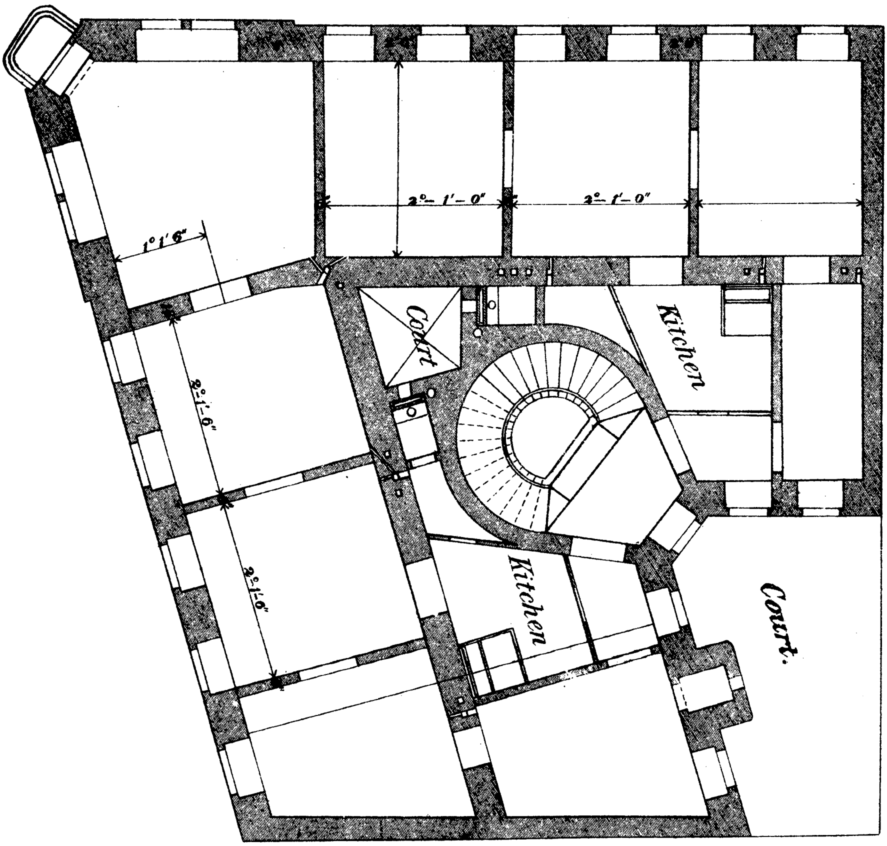
Apartment House in Vienna. Pl. II. (E.)



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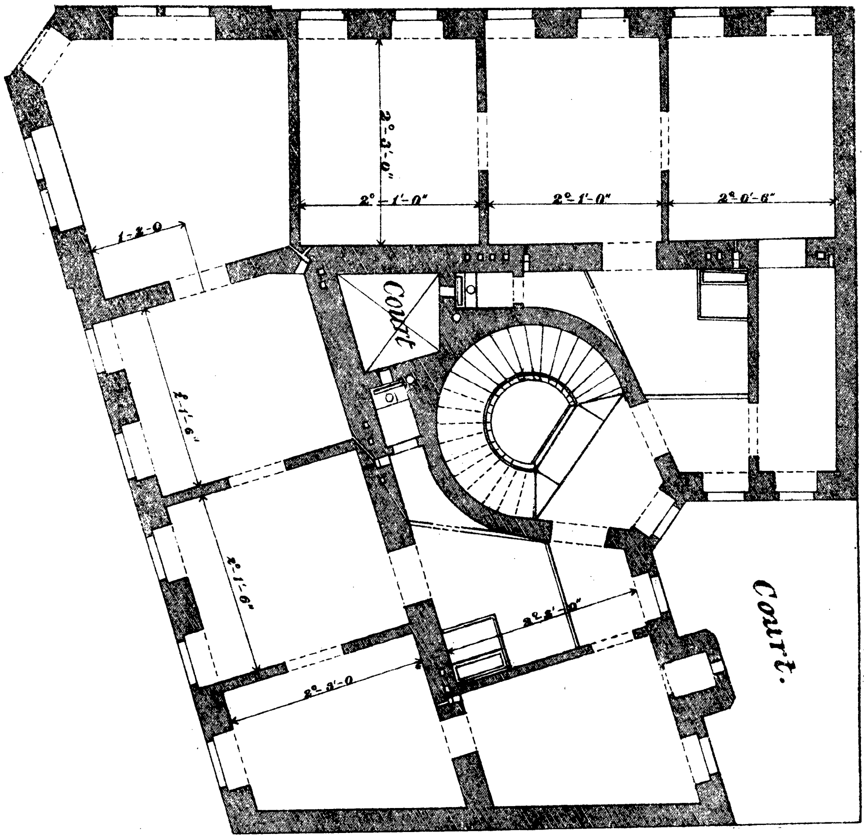
Apartment House in Vienna. Pl. II. (F.)



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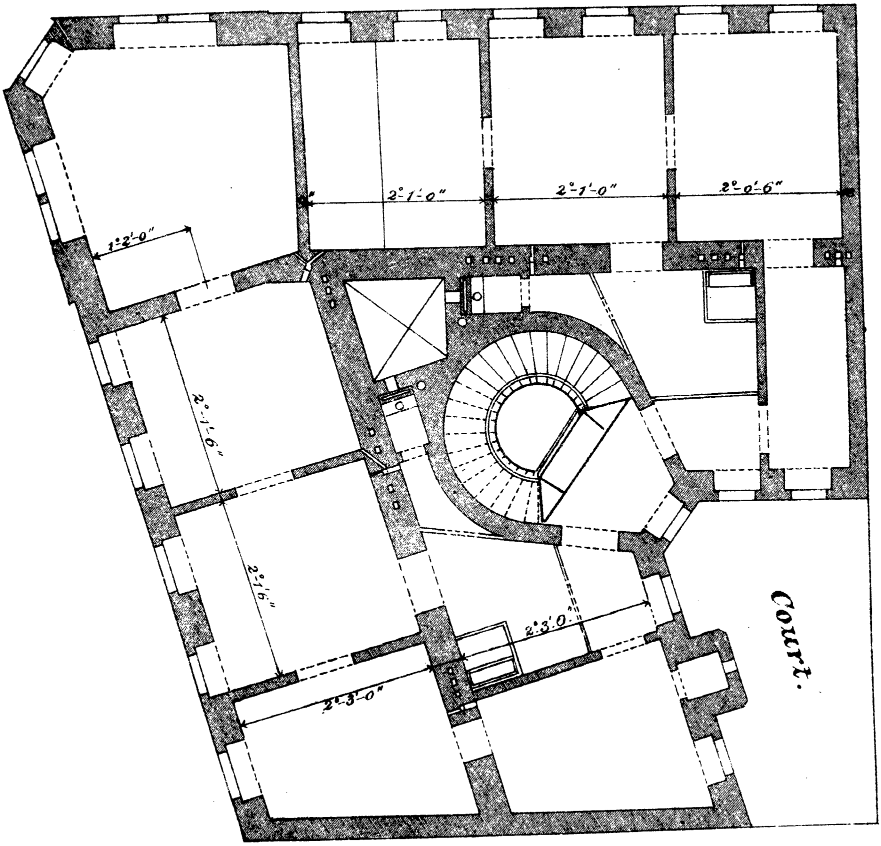
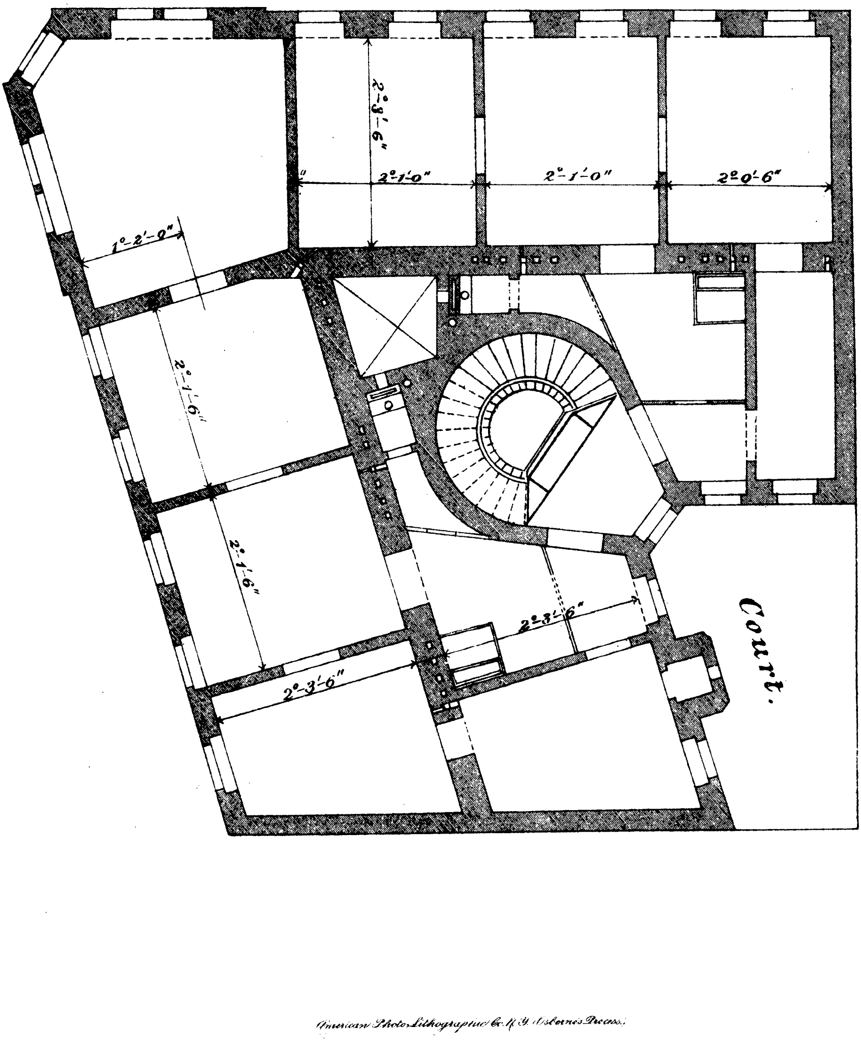
Apartment House in Vienna. Pl. II. (G.)



Apartment House in Vienna. Pl. II. (H.)



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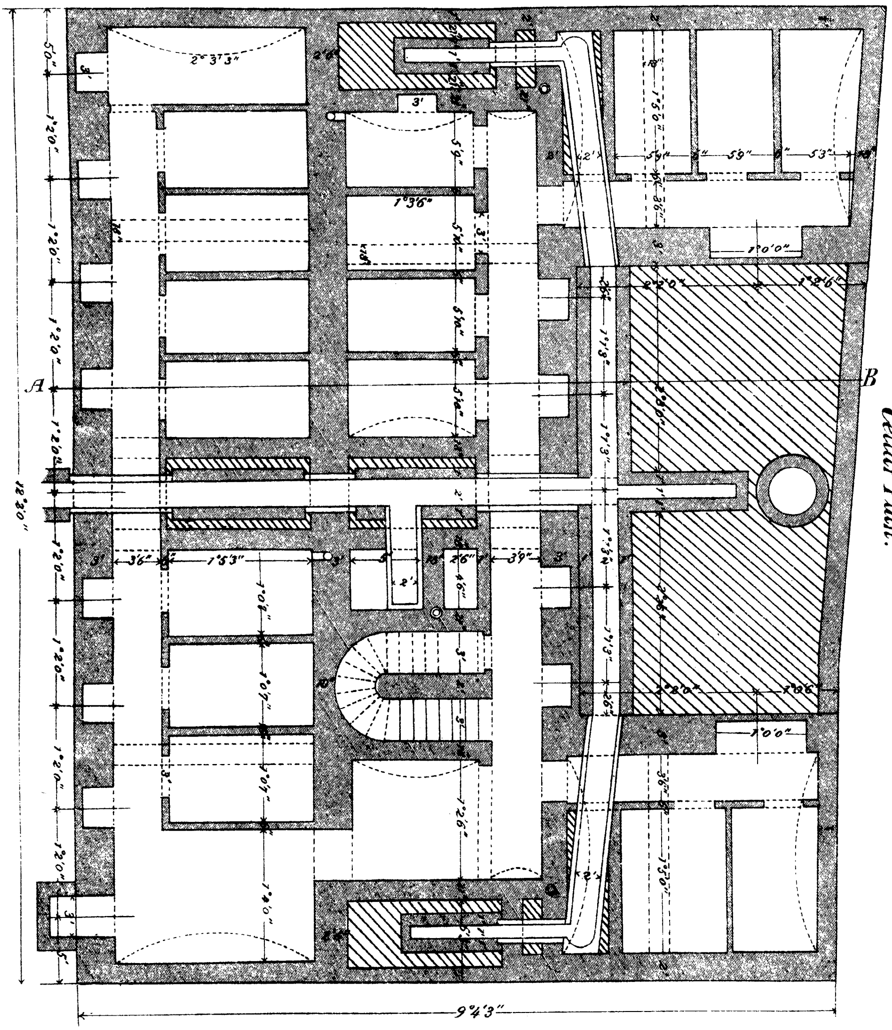
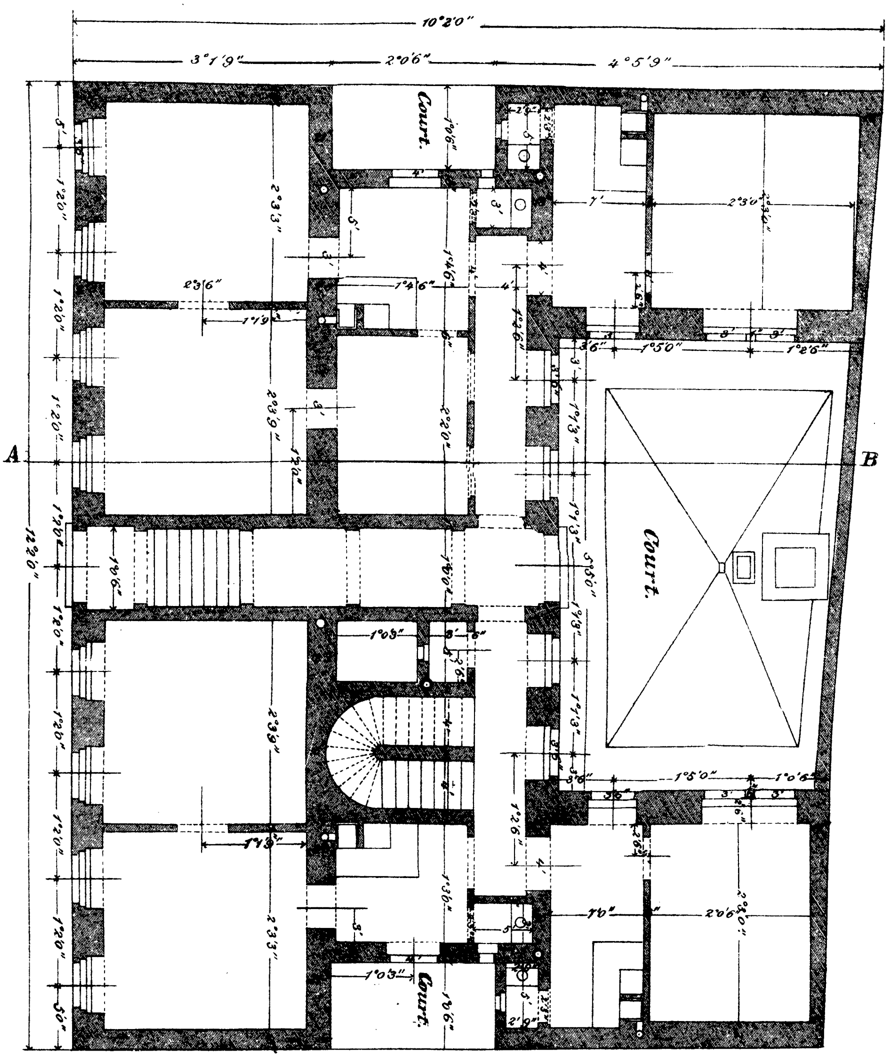
Apartment House in Vienna. Pl. III. (A.)

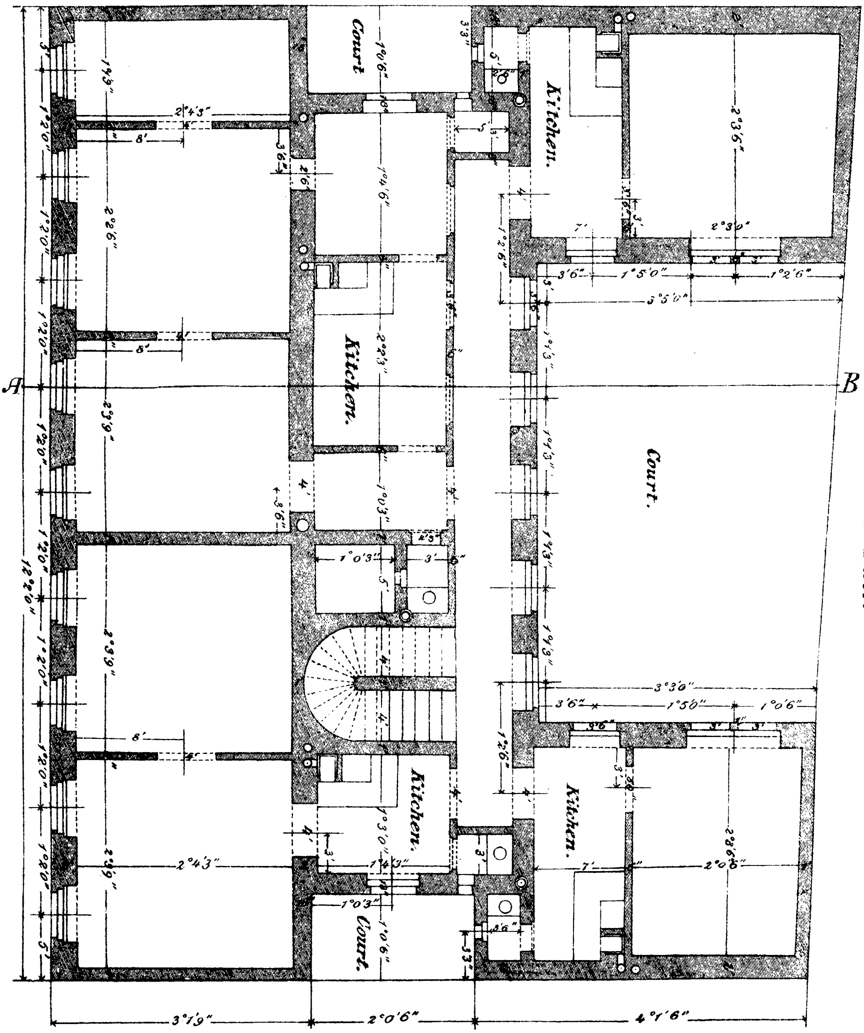


American Photo Lithographic Co (Osborne's Process)

Apartment House in Vienna. Pl. III. (B.)



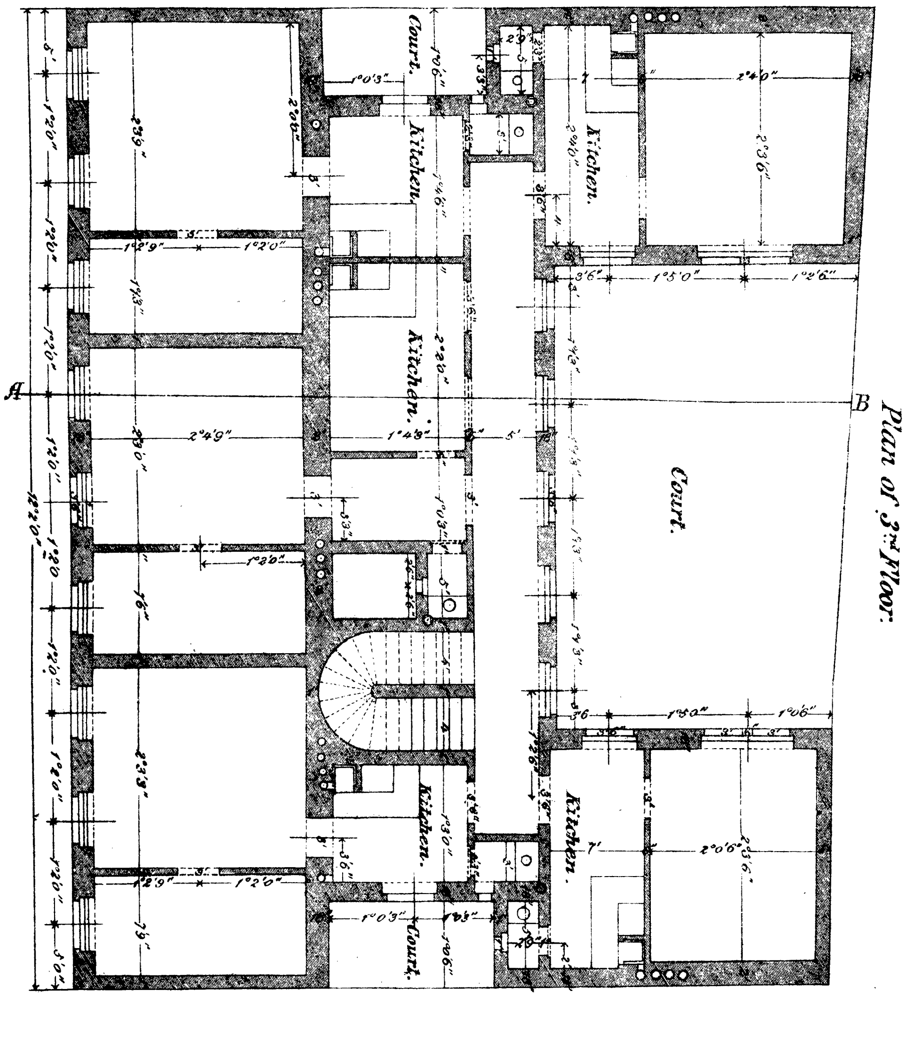
Apartment House in Vienna. Pl. III. (C.)



Plan of 1st & 2nd Floor.

American Photo Lithographic Co. N.Y. (Osborne's Process.)

Apartment House in Vienna. Pl. III. (D.)



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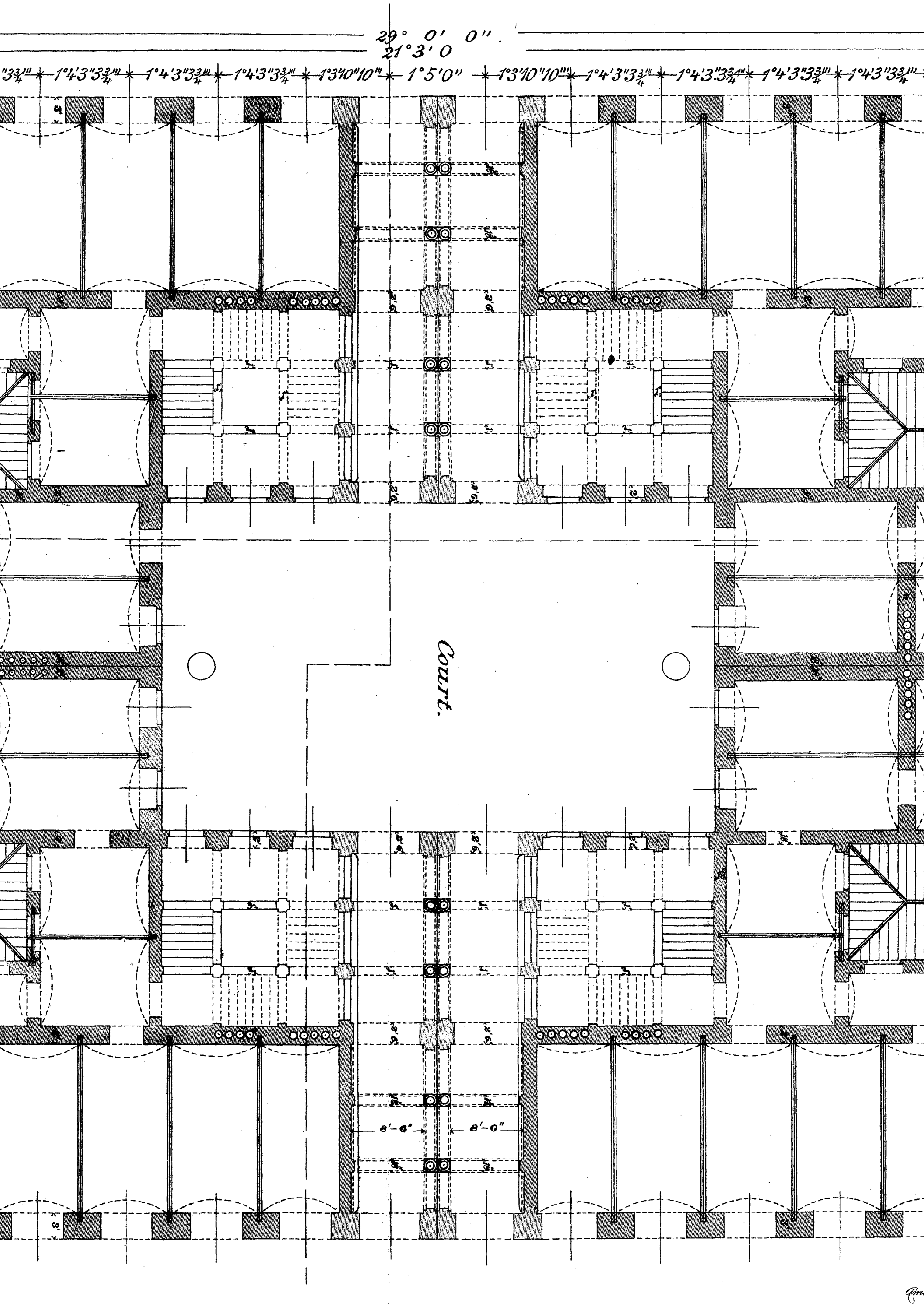
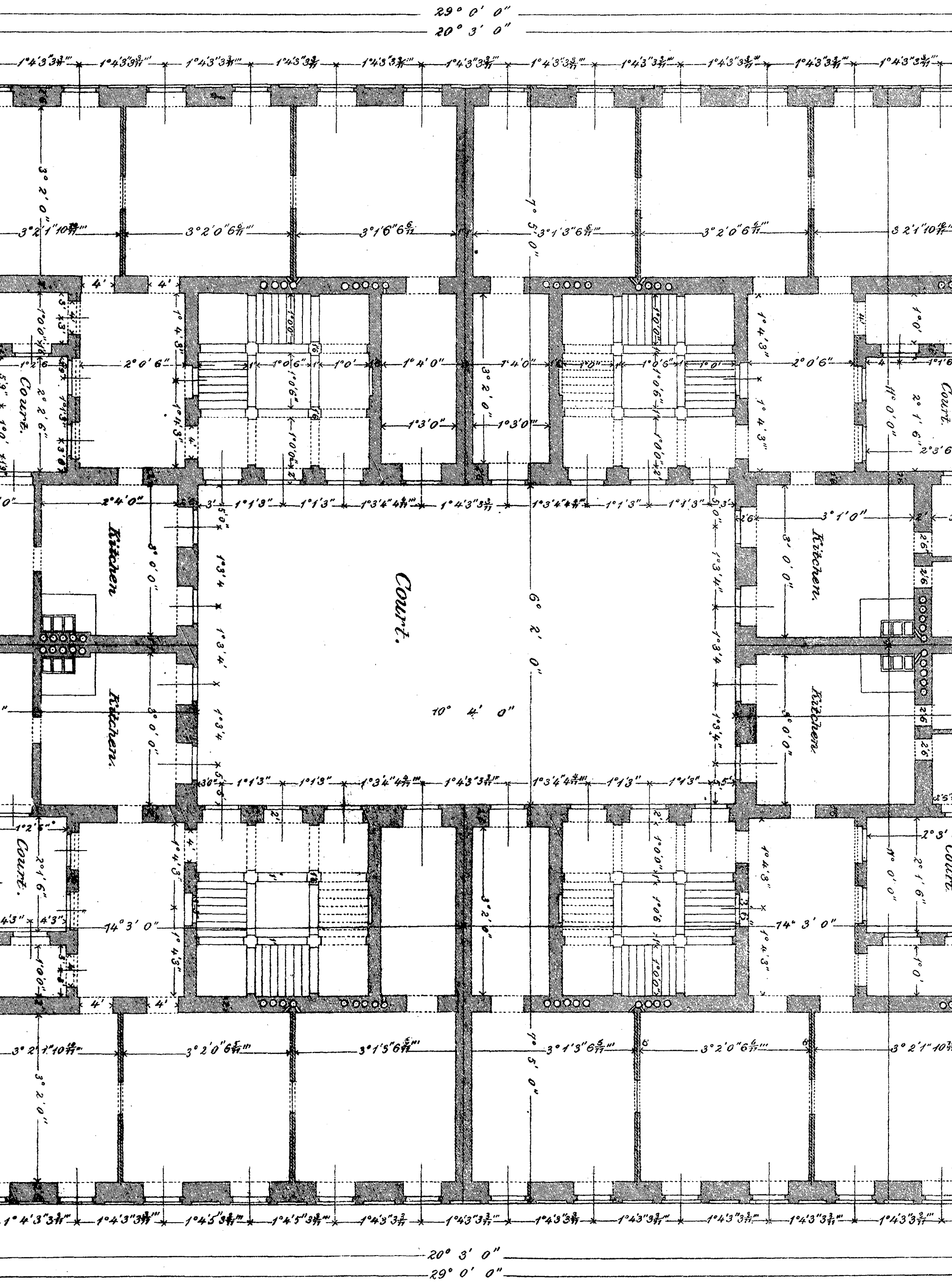
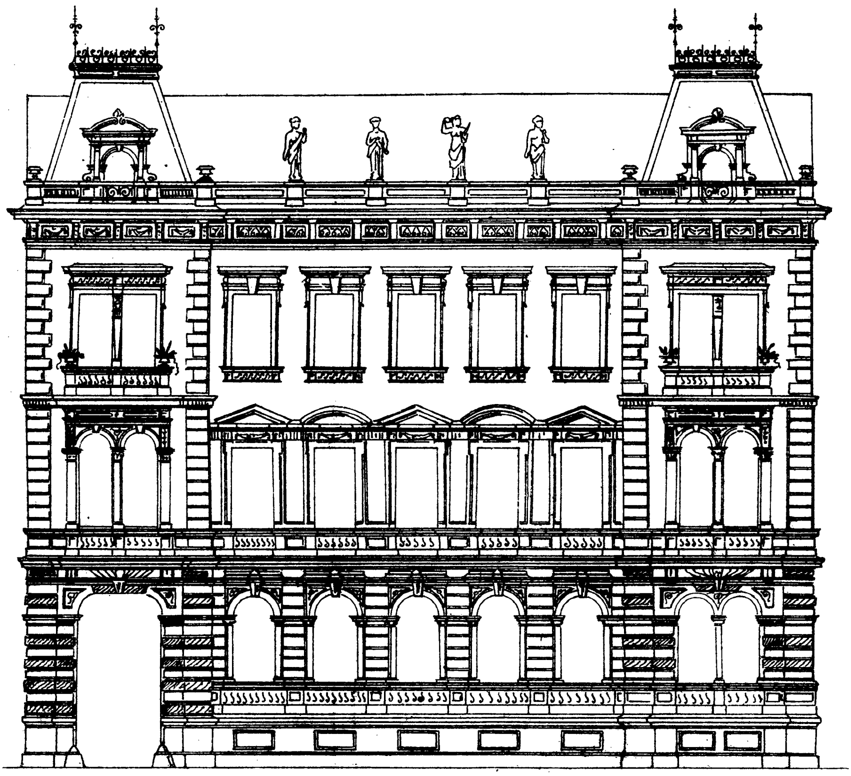

29° 0' 0".
21°3' 0
1°4'3"3¾"
1°3'10"10"'
1°5'0"
Court.
8'-6"
8'-6"

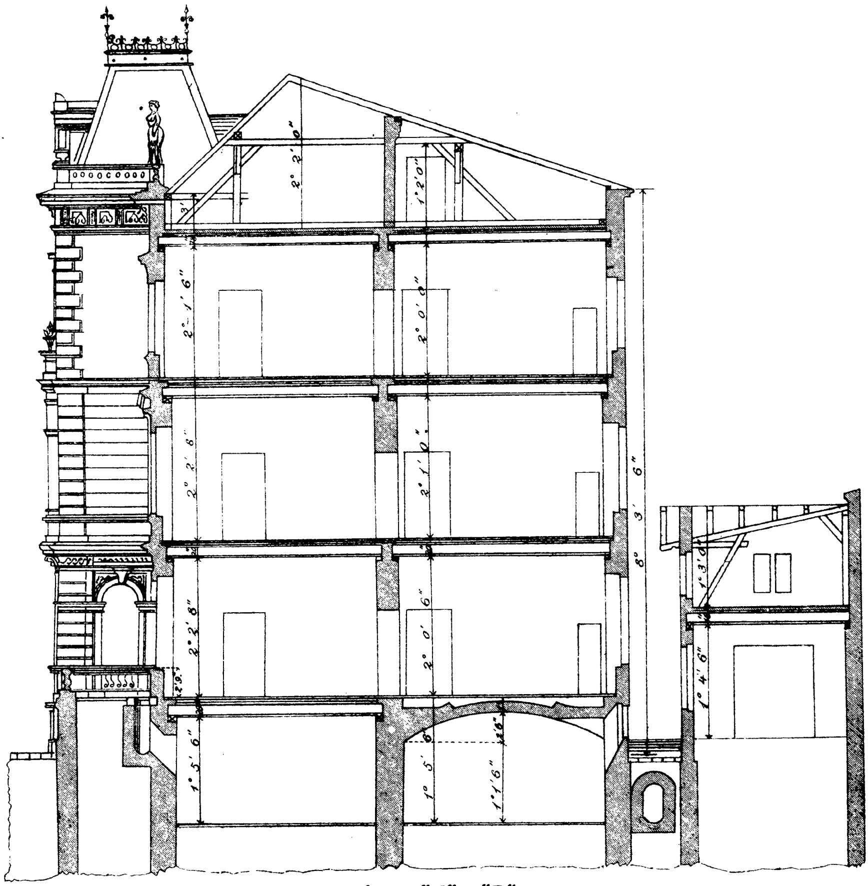

29° 0' 0"
20° 3' 0"
Court.
Kitchen.
Kitchen.
10° 4' 0"
6° 2' 0"

Apartment House in Vienna. Pl. V. (A.)



Apartment House in Vienna.

Pl. V. (B.)



Section "A" to "B".

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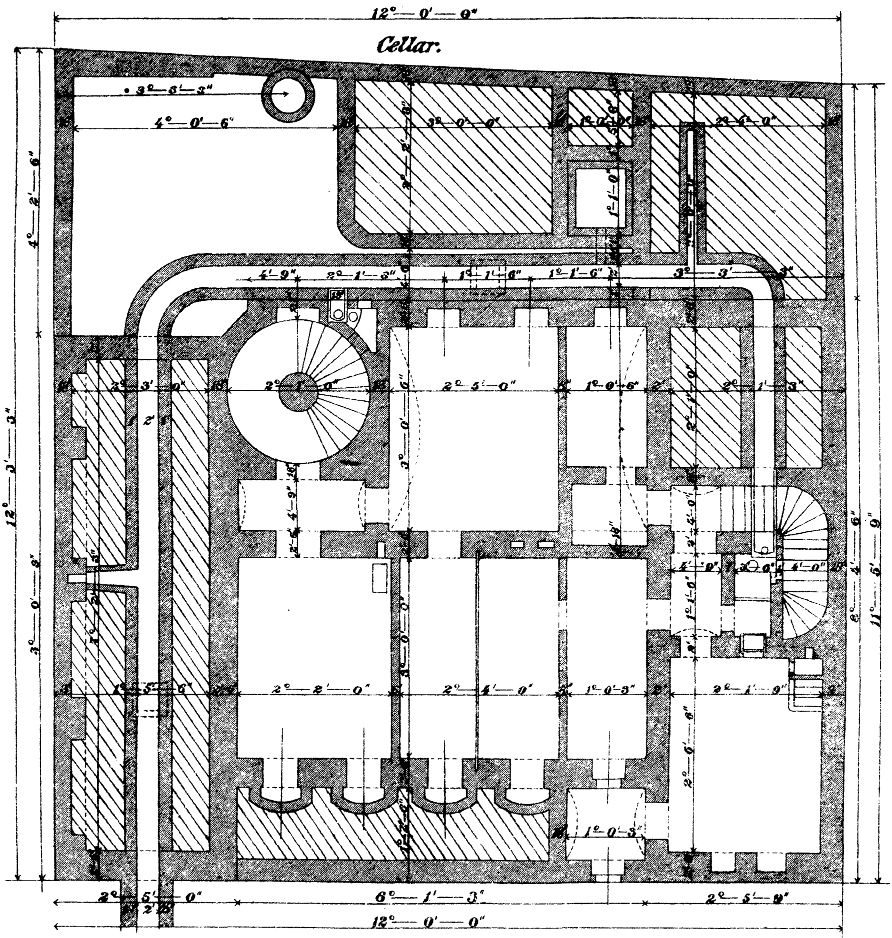
Vienna Exhibition 1873. Architecture.

Apartment House in Vienna. Pl. V. (C.)



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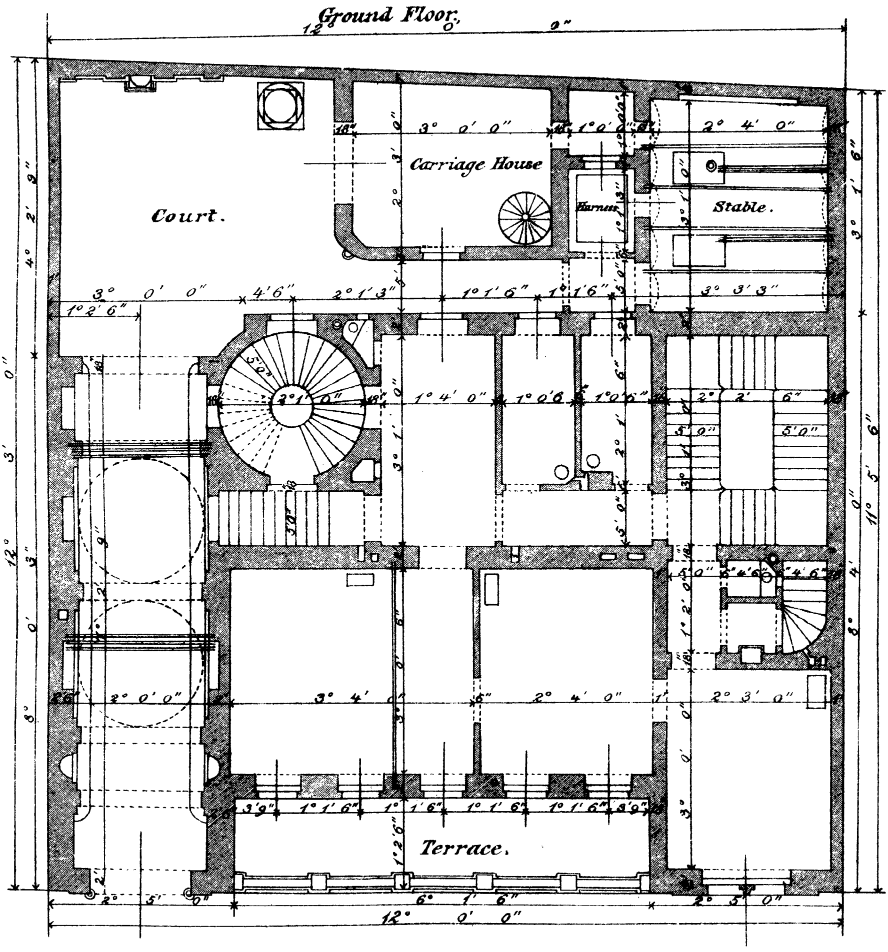
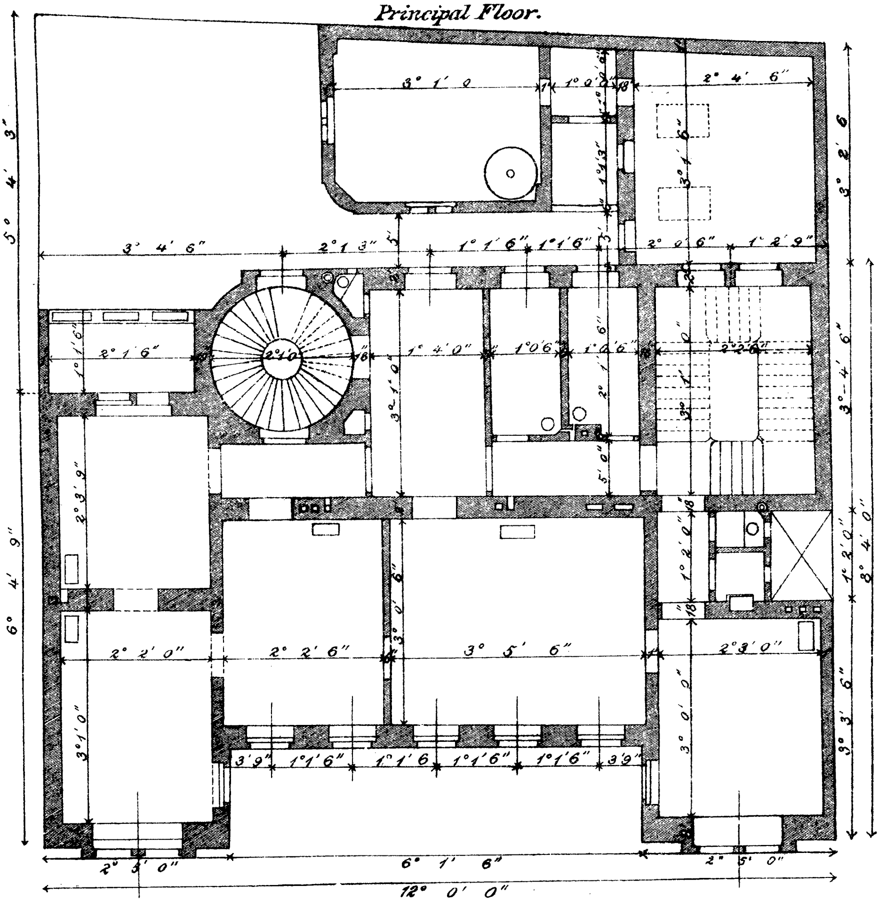
Apartment House in Vienna. Pl. V. (D.)



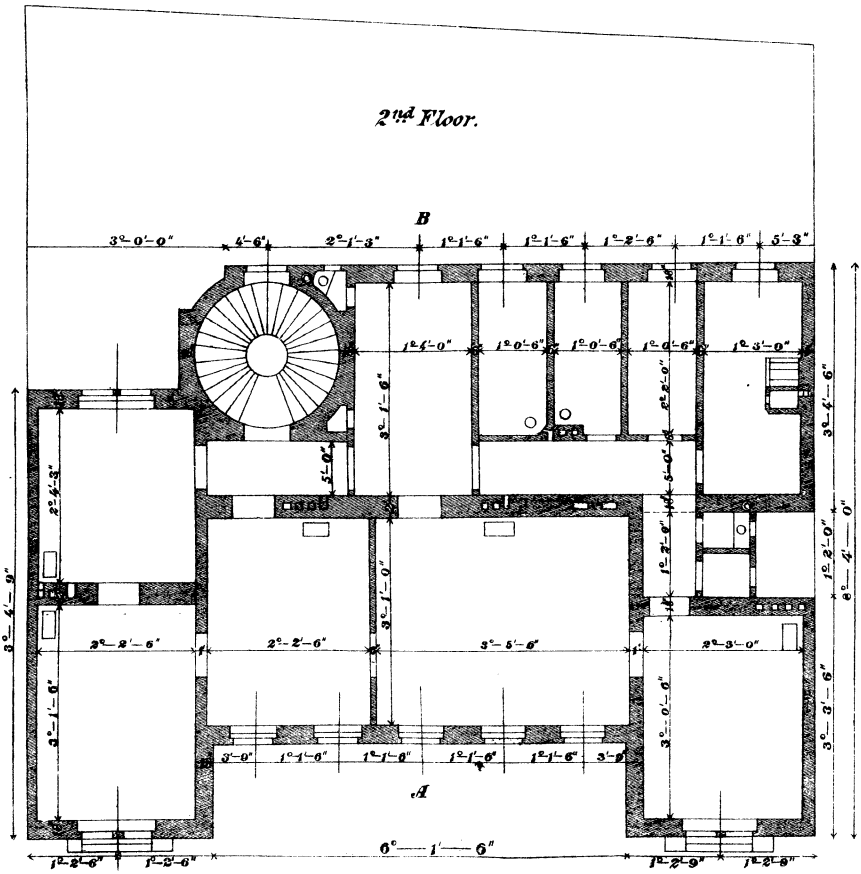
American Photo-Lithographic Co. N.Y. (Osborne's Process)

Apartment House in Vienna. Pl. V. (E.)

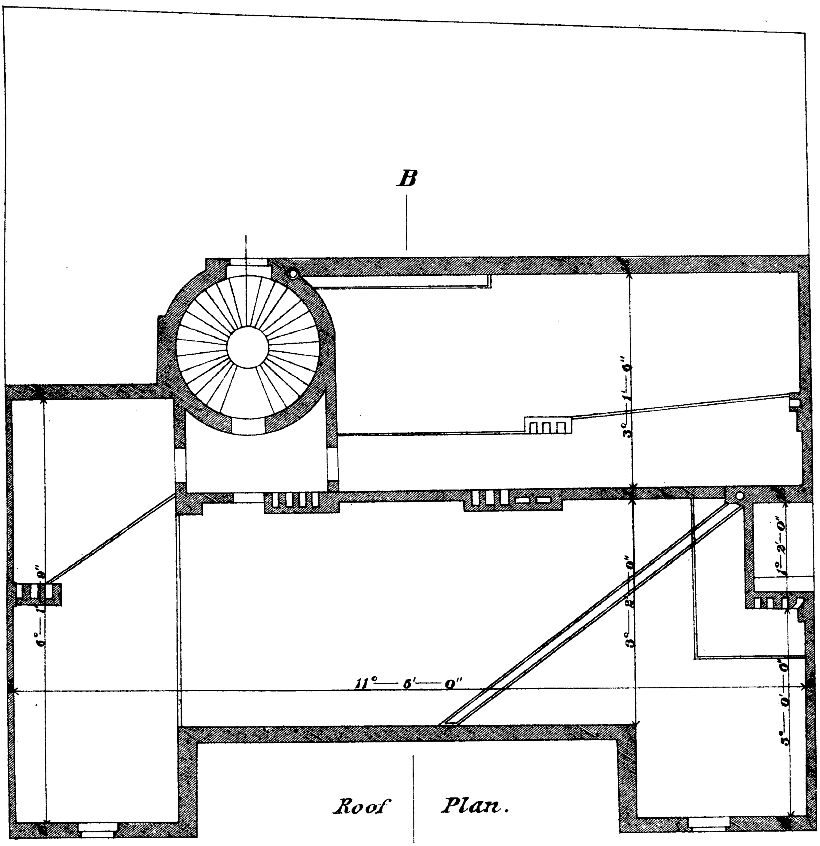
Principal Floor.



Apartment House in Vienna. Pl. V. (F.)



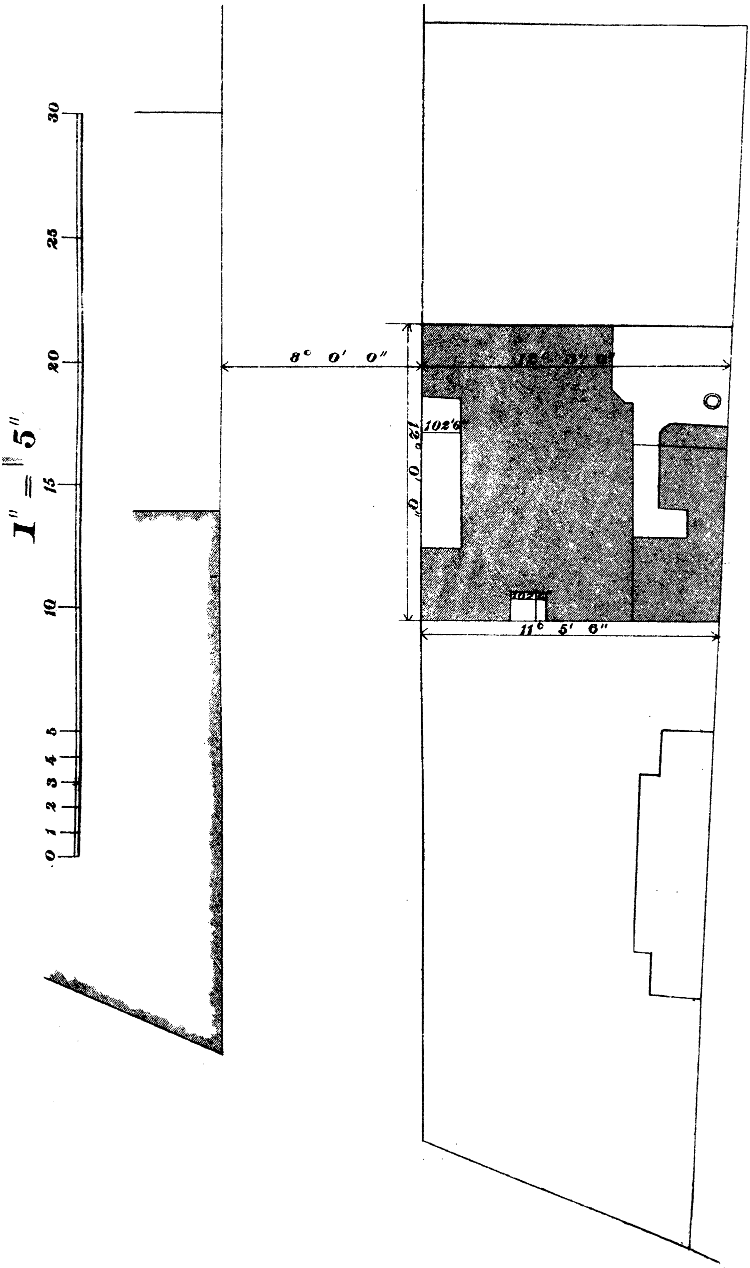
Apartment House in Vienna. Pl. V. (G.)



Roof Plan.

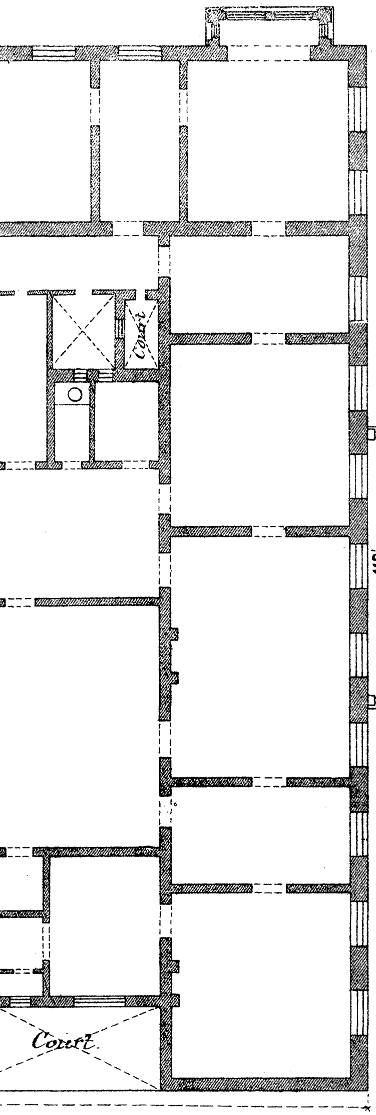
American Photo-Lithographic Co. N. Y. (Osborne's Process.)

Apartment House in Vienna. Pl. V. (H.)

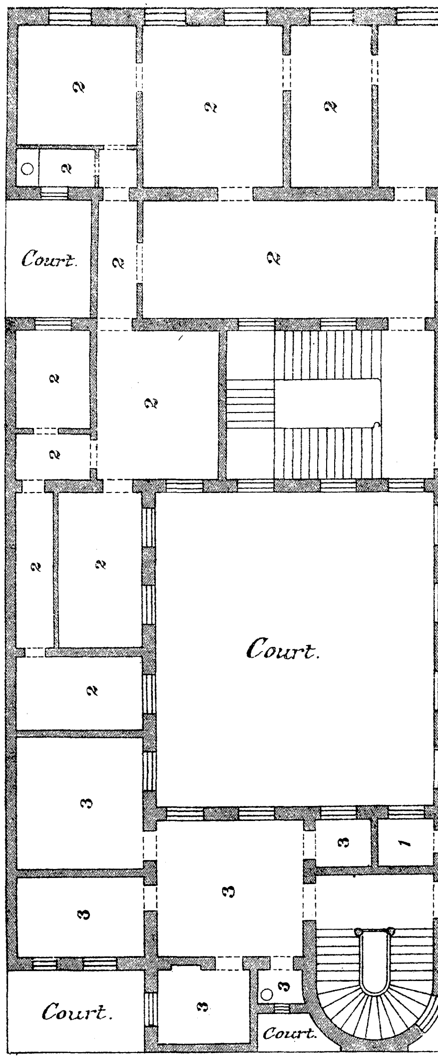


Plan of a First Class Apartment House, Vienna.

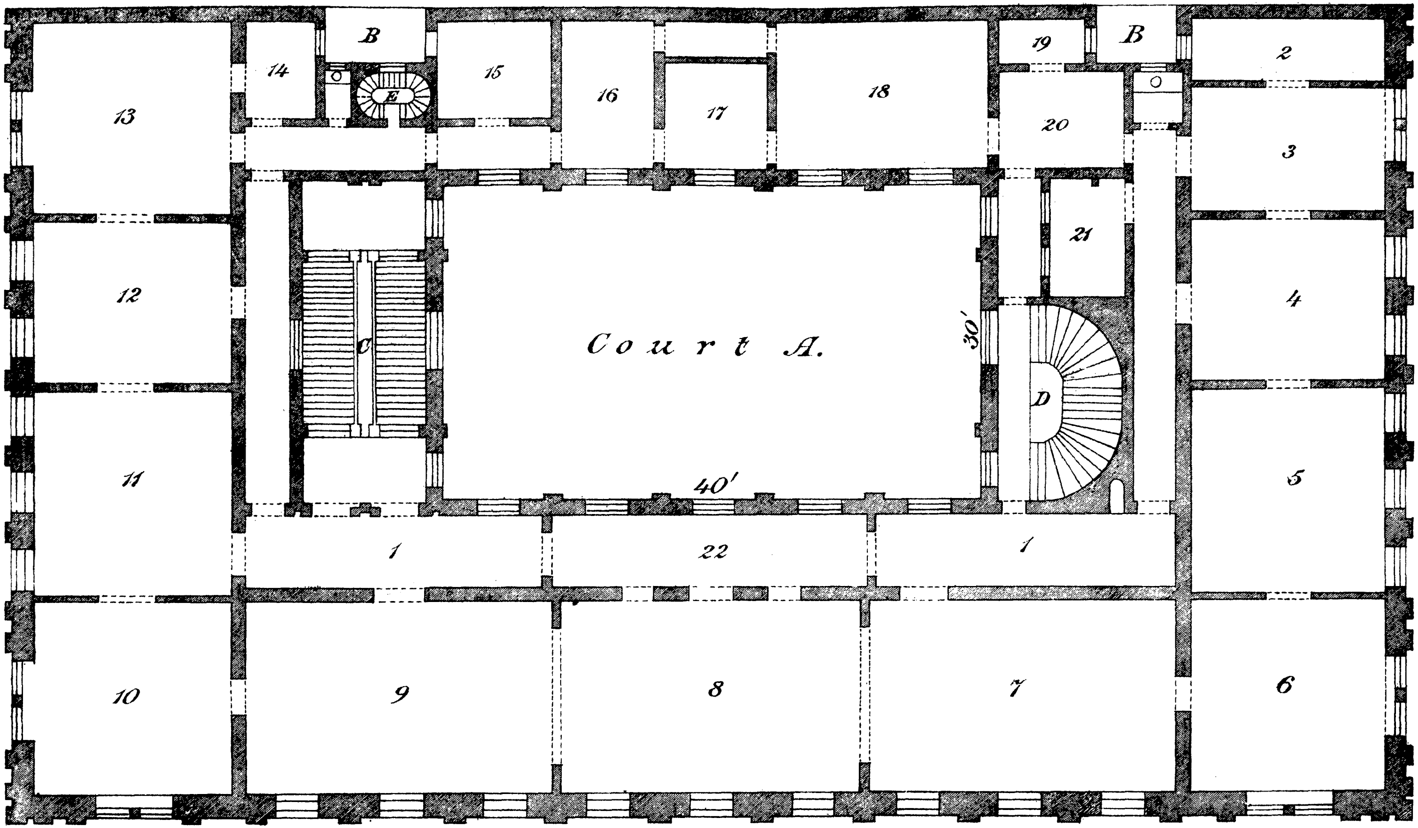
Floor.



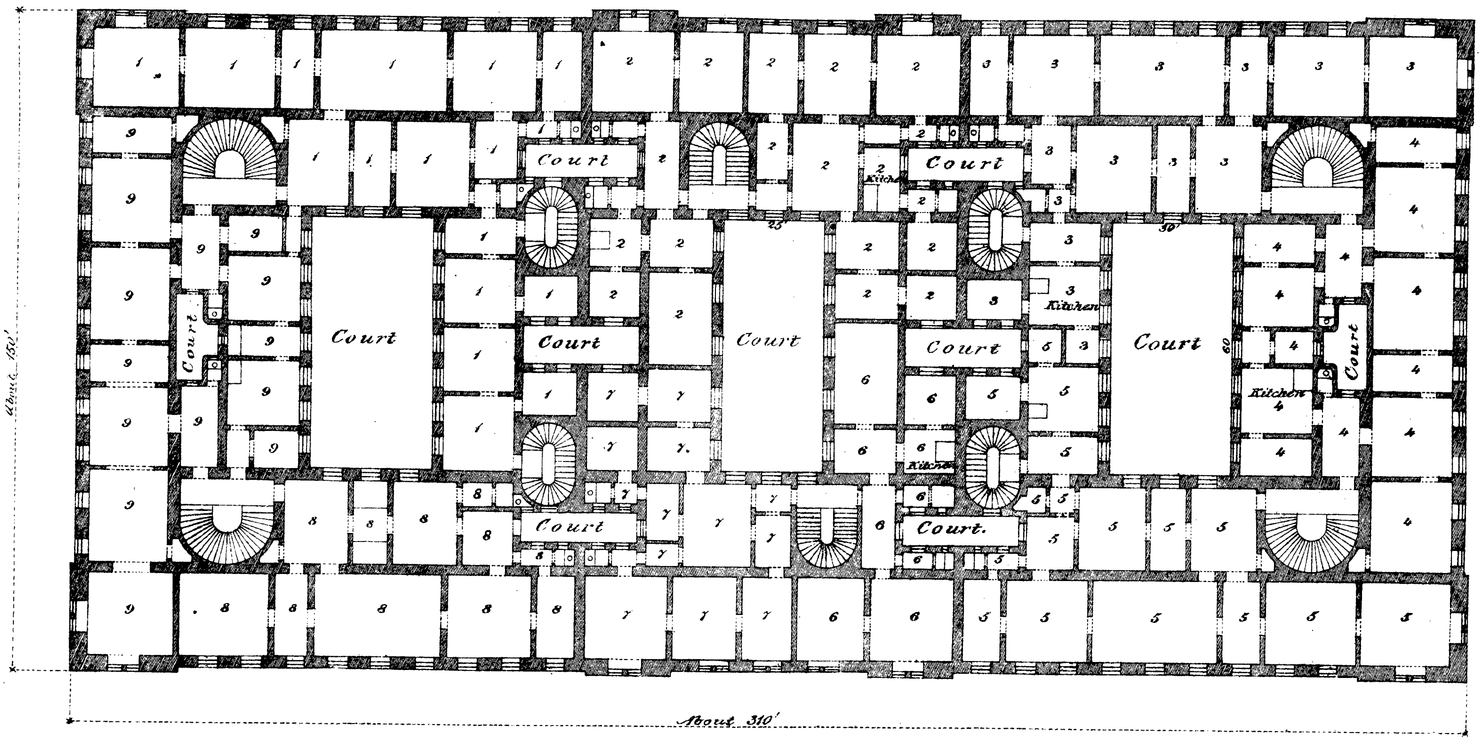
B. 2nd a



„Palais" of L. Epstein — Principal Floor.



Principal Floor of Apartment House, called "Henry's Court," Opera Ring, Vienna.



American Photo-Lithographic Co. N. Y. (Osborne's Process.)

Principal Floor of Apartment House by the "Union Building Association" of Vienna.

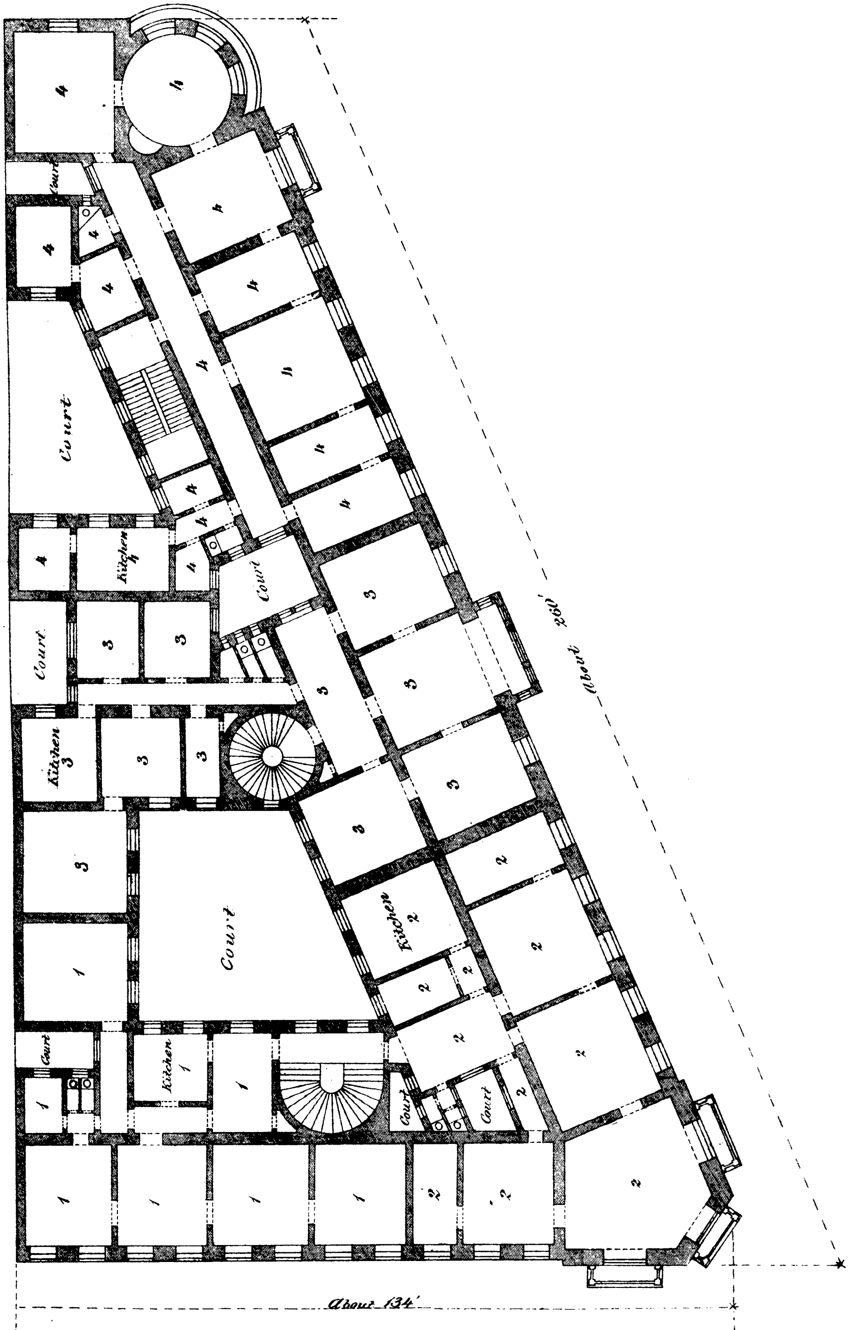


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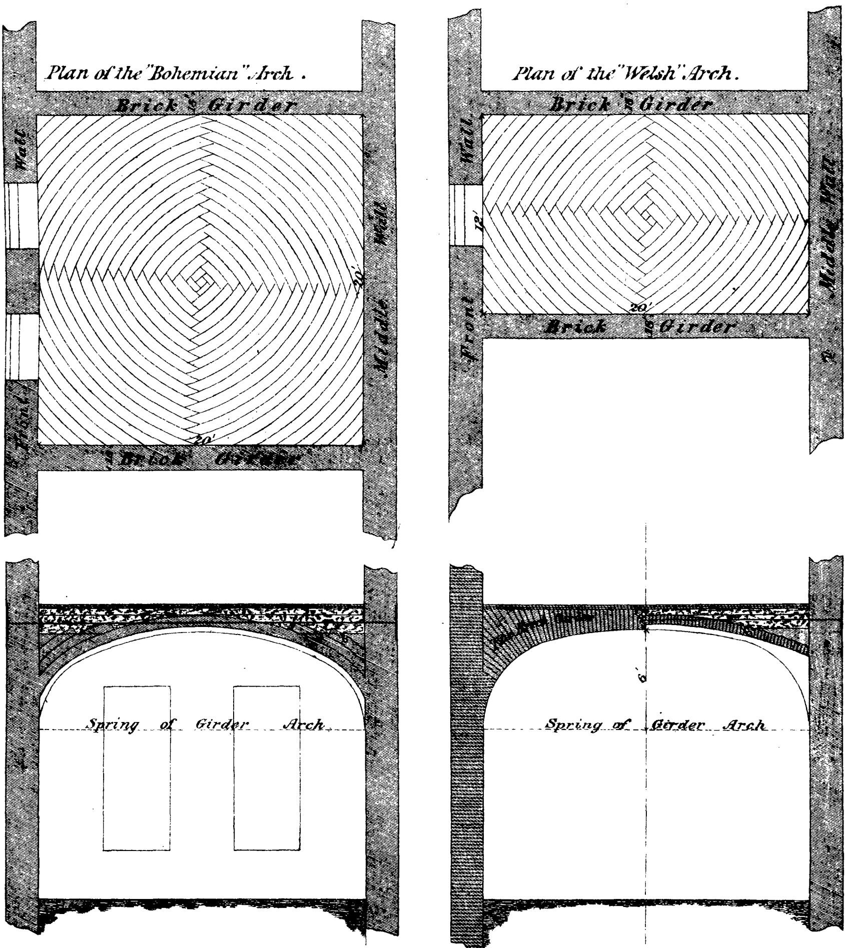
Plate X.

FAÇADE OF A DWELLING IN VIENNA.

Details of the self-sustaining "Platzel," or Flat-crown Arches, as constructed at Vienna.



Section of the Bohemian Arch.

Section of the Welsh Arch.

American Photo-Lithographic Co. N.Y. (Osborne's Process.)

B.

ARCHITECTURE AND MATERIALS.

N. L. DERBY.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

ARCHITECTURE

AND THE

MATERIALS OF CONSTRUCTION.

BY

NELSON L. DERBY, B. A.,
HONORARY COMMISSIONER OF THE UNITED STATES

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

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CHAPTER I.

TERRA COTTA, TILES, AND CEMENTS.

TERRA COTTA; MOLDED BRICK; AUSTRIAN MANUFACTURES; TILES; BONDING WALLS; PECULIAR KINDS OF BRICKS; LATHING AND FURRING; CEMENTS; FOUNDATIONS; BASINS; CASTINGS; MASTIC; CEMENT BREAKWATERS.

1. TERRA COTTA.—Among the building-materials which met the eye in the greatest abundance at Vienna were terra cotta and molded brick. Some American companies are now commencing the manufacture of these articles, as well as of tiles, for paving purposes, although we still import largely.

2. The most beautifully designed and most richly colored terra cotta was exhibited by the Austrians themselves. It is of a darker color than the English, something between cream and chocolate, and not so hard as that of the latter country. It stands frost, however, very fairly, and is produced at a moderate figure in money. Brackets, columns, balusters, and also fountains and statues, were exhibited by the Austrians and the North Germans. The English themselves were excessively astonished at the perfection which this manufacture had reached in Austria and the beauty of the designs. It is well known that this material is more durable than stone, as is now apparent in the British Houses of Parliament in London. It also does away with the great expense attending the reproduction of the same pattern in stone. The architectural forms above cited are, in many cases, used merely for ornament, and sustain no weight; they are therefore made in this case to the greatest advantage of terra cotta, and sometimes of cast cement, which will be referred to later.

3. As a contrast to this, we may call attention to the enormous quantity of cut granite employed in this country, at which foreigners stand aghast.

This most intractable of stones is never used on the continent for any other portion of a building than the basement and foundations. Our own experience shows that it has far less value than brick in resisting fire, while the process of cutting it is most laborious and expensive.

4. The tendency of modern improvement is certainly to the production of effect with economy of money and material. The French will prepare a better meal than any other people with less matter and at half the expense. The Germans will get solid enjoyment out of small sums of money, but with us extravagance and lack of result are too apt to go hand in hand. The stone used for building purposes in Paris can be

cut with a knife when first quarried, and becomes quite hard on exposure to the air. The utmost richness of design is thus rendered possible at small expense.

5. Where cast iron is used, as in this country, some money is saved by using few patterns and making the ornaments of every story of a building alike. The result is not beautiful, but it is cheap. But why should this peculiarity of iron be copied in the New York post-office? Differences of design for the different stories were possible without additional expense, but now every door and every window on the exterior is alike, and the eye, wandering over its vast expanse, turns sickened and wearied away to gaze at some more congenial object. The neglect of some simple matter like this has been the cause of the failure of many of our most prominent buildings. The new cathedral-building on Fifth avenue, New York, is an imposing and striking building, but in the traceries of the windows and above the main portal, which in the old types of Europe are treated with the delicacy and lightness of lace-work, there is here a heaviness, a clumsiness, and a rigidity excessively disappointing to the lover of art. The New York Evening Post not long since, in an editorial, said that our people are not sufficiently educated in art-matters, or in building, to form independent opinions on these subjects. They are too apt to believe implicitly in the dictum of professional men, especially if they possess the reputation of having studied in foreign schools. We are, however, improving, and it seems the duty of the Government to foster in every way the growth of art-museums and schools, for which the South Kensington Museum, in London, forms the best existing model.

6. Bricks.—The molded brick exhibited at Vienna are made with little additional apparatus and form a very effective material for producing architectural effects. Similar varieties have been used for centuries in Northern Italy, and are now being taken up quite extensively in England. Hollow cellular bricks were to be seen in large numbers; these are pierced with longitudinal holes, reducing the weight about one-third, and are quite useful in springing arches and vaults between iron beams in the construction of fire-proof floors. They are made also in the skew-back pattern and are much superior to the compositions lately introduced among us for similar purposes. A few are manufactured at present in New York. The ordinary building-brick of Vienna is larger than ours, being at least a foot long and is excessively porous. They are laid with the exterior half of the joint open and an inch wide, for the purpose of keying on a coating of cement, which is there used as a substitute for mastic, and is durable, cheap, and capable of adaptation to all architectural forms.

7. The most important terra-cotta and brick works in Austria are the Wienerberger, in the environs of Vienna, and much of the beauty of the modern portion of this city is to be attributed to the use of their materials by Austrian architects; they are always pleasing in design and in color.

8. The best exhibition of tiles was made by England. We all know the Mintŏn and Maw tiles, and we import such a quantity of them that little need here be said in regard to them. The delicate patterns, however, which these firms produce render it impossible to bake them to a sufficient degree of flintiness, and the result is that they do not stand much wear when used for pavements. They lose their colors and chip around the edges, as may be seen in the Parliament Houses in London, and in some buildings in this country. Other more expensive and more durable tiles are made by cutting out the pattern to a depth of an eighth of an inch and filling it up with colored paste. The whole is then baked together.

The use of tiles for dadoes and wainscoting is becoming prevalent abroad, and plain glazed tiles are used in England to cover the entire walls of water-closets, bath-rooms, and kitchens, as they can be readily washed, and retain no malaria nor odor.

Tiles of clay or earthenware—those above referred to having a kaolin or China-ware basis—used for roofing purposes, were exhibited. Some of these were flat and were used exactly like slates; others had various curved shapes for rendering the joints tight, and still others were glazed to enable them better to shed the rain. Their weight renders them less liable than slate to removal by the wind, and their red color gives a very picturesque effect to the roofs. They are also more durable than slate, but, being heavier, they require heavier timber in the roof for their support. One eccentricity in this line were tiles of glass; these, as well as the earthenware, are better non-conductors than slate.

9. It may not be out of place, in this connection, to refer to the old Roman tiles, seen still in many parts of Europe, in a good state of preservation, especially in the remains of aqueducts and in such structures as the great arched openings in Rome. They are some 3 inches in thickness, and often 2 feet long by 7 inches in width. They are used to bind together walls constructed mainly of rubble or small stones. Once every two feet, or thereabouts, in a vertical direction, the stone-work is carefully leveled off and two or three courses of these tiles are laid in bond. The resulting structure is of great strength, as its duration until the present time sufficiently proves. The regular recurrence of the brick or tile work also gives a good effect, breaking the masses quite pleasingly.

10. There is no reason why this form of masonry should not be adapted to modern wants in the construction of piers, and even in buildings, lessening, as it would, the great expense to which our fondness for cut stone leads us. The structure would be as fire-proof as any form of masonry. I will advert, in this connection, to the custom in Vienna, made a necessity by the very good building-act there in force, of tying all brick walls, especially those containing arched windows, by rods of wrought iron, imbedded in the masonry and passing horizontally above the openings from end to end, where they are anchored fast.

Another clause of the Viennese building-act renders it necessary to construct the attic-floors of brick to prevent the timbers of the roof from falling through into the lower stories in case of fire. This was the reason for vaulting the foreign cathedrals beneath the wooden roofs, the roofs themselves again preserving the vaulting from the disintegrating effects of rain.

The best brick bond for ordinary walls is acknowledged to be the Flemish or the English. Headers and stretchers are placed alternately in each row, the headers being over the stretchers alternately in a vertical direction.

11. The objection to the use of these bonds in America is the fact that they require more face-brick than our own, and workmen, when compelled by architects to use them, have been known to put in half-bricks, which look on the completion of the wall exactly like headers, but naturally serve no good purpose. The writer has nowhere seen better bricks or better brick-layers than in America. Our joints are by far the thinnest of any in the world, but with all our regularity and exactness there has been, until lately, but little art displayed in brick-work with us. The architrave of a window can be readily formed of brick, all molded to one pattern, and the same is true of continuous string-courses and cornices; brackets of terra cotta can be built in under the latter, and keystones of the same material inserted into the arches. Many of the most pleasing effects in Italian architecture have thus been produced at no great expense. The method is as feasible here as the construction of cast-iron buildings, which are regarded by critics as monstrosities, especially where the attempt is made to give them the appearance of white marble or of other stone.

12. Other bricks were formed so as to dovetail into one another; and they are useful in the construction of circular towers or of "swell fronts" in brick. Their additional strength renders a reduction in the thickness of the wall possible. The use of black bricks for ornamental purposes has become quite common of late in America. The color is given them by insertion into coal-tar. In France black bricks are also constantly met with, but they are there colored by more intense baking. They are of the nature of clinkers, and, as used in France for headers in the English or Flemish bond, give a neat appearance to the wall. The coal-tar process is in all probability not productive of a permanent color.

The other forms of brick which were noticed were several large varieties, measuring 18 by 9 by 4½ inches, used for building cornices. They are manufactured by the Wienerberg works. Wedge-shaped, solid bricks were to be seen, for arches, and face-brick, glazed in different colors. There were no machines exhibited for turning out pressed brick which would compare with American machines in neatness or in rapidity of working.

13. In Austria the use of furring and lathing is infrequent, it being customary to build brick walls hollow, to secure warmth and dryness, and

then to plaster directly upon them. The use of inflammable material is thus avoided and no space is lost. Iron lathing cannot be considered a substitute unless the furring is also iron. In another part of this paper the excellent provisions in the Vienna building-act to secure fire-proof buildings will be referred to. Before leaving this subject we will call attention to the fact that hollow bricks, both square and skewbacks, are manufactured in this country by the firm of Beckwith & Co., of New York. They also import a very hard German tile, which leaves something to be desired in its design and color.

14. CEMENT.—There were a great many specimens of this material exhibited, the strongest being the English varieties, though many of the Austrian were excellent. The basis of cement, as is well known, is a limestone containing clay. Clay mixed artificially with lime, and thus burned, will also yield a good cement. The Romans, when constructing works in foreign parts, and when pressed for time, often mingled pulverized brick with common mortar, and produced in this manner a very good substitute for cement. In view of the favor into which red mortar for brick-laying is growing in this country, this is a hint which might be utilized. A brick wall laid in cement is stronger and much dryer than one laid in ordinary mortar, and certainly, if pulverized brick is to be cheaply procured, its addition to mortar can do no harm.

15. A curious process has of late come in vogue in England, in connection with the so-called Queen Anne architecture, of carving brick masonry. With the use of red mortars pleasing effects can be produced in this way, though porous bricks are better adapted to it than face-bricks, as the latter show a color when cut different from that on the surface. Inasmuch as many prominent architects of England are using this form of decoration, it may be inferred that there is something in it.

16. It is common abroad to lay all foundation-walls in cement; and foundations consisting entirely of cement are coming by degrees into general use. Thus were founded the piers of the great rotunda at Vienna, and these have shown no signs of settling or of other weakness. Here again is an economy on the use of hewn stone, as we see it used, for instance, in New York, where a half-acre has been covered with enormous granite blocks to form an anchorage for the cables of the great Brooklyn suspension-bridge.

17. In a quarter of Vienna, some two and a half miles from the Exhibition, fifty workmen were employed during the progress of the latter in constructing an enormous basin to receive the water from one of the highest-playing fountains of the world. It is, perhaps, 200 feet in diameter, and the foundations commence 15 feet below the surface of the soil. Trenches were first dug and lined with boards, then a mixture of one part cement to three parts clean sharp gravel was shoveled in and rammed. On reaching the surface, a mixture of one part cement and one part sand was used to form the bed and the coping, and the

whole was neatly turned, rubbed down, and finally polished. It presents much the appearance of marble and stands very well.

18. In a previous part of this paper castings in cement were referred to. Many of these are made without adding sand, and are useful where the same ornamental form is repeated in a building, whether in brackets, balusters, dentils, egg-moldings, or any other ornaments which would require much repetition in stone-cutting. It is not as strong as granite, nor is glass as serviceable as a diamond for many purposes, but they both answer very well in their way. The cement is vastly less expensive, and for these purposes is sufficiently durable.

19. A building was erected on the grounds, by one of the Austrian cement-companies, entirely of this material. The roof was internally nearly flat, externally sloping to the eaves, and formed of one mass of cement, varying from the edges to the center from a foot and a half to 10 inches in thickness. The building was about 18 feet square and had an external stairway curiously made of a block of cement for each step, supported only at one end, which was imbedded 10 inches in the wall. This led to the roof, which was surrounded by a parapet of cement and was seemingly capable of supporting the weight of many people. The only improvement that the writer could have suggested was a covering of tin or zinc for the roof, not to keep out the rain, but to prevent the wearing effects of the weather on the large mass of cement exposed. Thus we have learned the possibility of shipping an entire building to any point desired, in barrels, needing nothing additional on the ground but water.

Large slabs of cement were also exhibited, to be used for paving-purposes, measuring sometimes, superficially, 6 by 10 feet, with a thickness of 4 to 6 inches. The writer has seen these built into a corner of a stairway, supported only by two adjacent walls, and standing very well as landing-places. By the processes above referred to very cheap and strong fire proof stairs are constructed in Vienna. Tiles of molded cement are also used for interior paving, and the New York firm mentioned above imports some of these from France, which are very pleasingly molded in cements with which various coloring ingredients have been mixed and formed into tasteful patterns. These do not wear as well as baked tiles, as they are liable to chip at the joints; but they are, of course, better in quality as the proportion of sand is diminished. Another form of flooring consists of cement, laid in mass, into which small bits of colored marble are inserted in regular patterns. The whole, when once set, is rubbed down with sand and holystone and polished. It is thoroughly impervious to water and vermin, and seems quite suitable for kitchens and bath-rooms.

20. A traveler arriving at Vienna is much struck by the imposing buildings which line the principal streets, their fronts stretching unbroken from 100 to 200 feet, their cornices heavy and projecting from $2\frac{1}{2}$ to 4 feet, throwing rich shadows, and well lightened by beautiful

combinations of ornament. The lower story is, in general, massive; ample piers support the masonry above, and perhaps only half of the entire width is sacrificed to show-windows.

The Viennese rely upon interior courts for light, and do not reduce the strips of wall between the windows until, as with us, the building seems to have hardly a leg left to stand upon. These structures appear to be built of a light, cream-colored stone, in no case darkened by smoke or time. They are, in reality, however, constructed by a combination of the processes above described. The cream-colored stone is only a coating of cement mixed with a golden-hued sand and well keyed into the open joints of the large porous bricks; while the ornamentation is made up of terra cotta or cast cement. The whole soon attains the consistency of marble and wears as well, while it is far cheaper.

The study of one of these buildings during erection is very interesting. The cornices, string-courses, and pediments of windows are built out roughly in brick; square holes are left for the insertion of brackets. Arches are sprung wherever necessary, without affecting the architectural appearance of the structure; and, finally, after the whole has been thoroughly moistened, the cement is thrown on and quickly planed into shape. It is then played on with a hose at intervals for several days. The front of a building is thus in a few hours transformed from a shapeless mass of rough brick-work to a beautiful architectural composition.

This must not be confounded with our process of stuccoing and mastic work. The differences are very essential. First, wide-jointed porous brick are used, which hold the superposed matter with the greatest firmness; then the basis of the coating is cement, and not, as with us, mortar.

Buildings thus constructed in Vienna never peel, though heavy frosts and long-continued rains are common.

21. Mastic has with us a very bad name; it is the symbol of cheapness and tawdry imitation; and so much is this the case that, often when, in talking with professional men, the subject of Vienna mastic has been introduced, it has been found impossible to get a hearing at all. There is considerable skill and experience required in working it; but we now have in our country a large number of Italians who understand the matter very well. A friend practicing architecture in New York states that he has for several years past been observing a building near that city which is covered with a similar cement-mastic. It is exposed on all sides to the winds and rain, yet it stands the weather remarkably well, and does not flake off nor crack.

22. One of the most remarkable purposes for which cement is employed abroad is the construction of the great breakwaters used to form artificial harbors at the mouths of canals upon the seacoast. These are to be seen at the Suez Canal in Egypt and in some parts of Holland.

Blocks measuring 18 by 9 and by 5 feet are cast in concrete, and by

their enormous size serve to resist the force of the waves and tides. An opportunity offered itself of inspecting a new ship-canal in Holland a year and a half ago, and the writer there walked out for nearly a mile on such a breakwater. Here, perhaps from the impurity of the sand used or from its too great quantity in proportion to the cement, the upper blocks were much rounded and worn, but the wall was firm. Such devastations are easily repaired by additional coatings of concrete, and the whole can thus be rendered as solid as in the beginning, a work which would be difficult in the case of stone without rebuilding the wall.

The failure of cement and concrete in this country is doubtless to a great extent due to the use of impure materials and of too great a quantity of sand.

CHAPTER II.

METALS USED IN CONSTRUCTION.

WROUGHT AND CAST IRON; CASTINGS AND FORGINGS; GALVANIZED IRON; CORRUGATED IRON.

23. WROUGHT AND CAST IRON.—Another material of great importance in its connection with building is iron, both cast and wrought. The expense of these two varieties is very different, so much so that very little ornamental wrought iron has as yet come into use in our country.

Girders and beams, it is universally acknowledged, should be made of wrought iron. Cast iron employed for these purposes is liable to yield to sudden shocks, and in case of fire, when it has become heated, the application of water snaps it. Wrought iron, when heated intensely, bends, and also gives way; but from its greater elasticity it is the only safe material under ordinary circumstances. Columns and pillars are better made of cast iron, while roof-frames should be wrought.

24. Some of the castings made abroad are of great delicacy, and it certainly is a pity that our street-lanterns and much of our architectural ornamentation are not more carefully molded. Sharp outlines add wonderfully to the effect of all architectural work, and these we rarely see in this country in cast iron.

Some of the most beautiful specimens of art which the Middle Ages have handed down to us are of wrought iron. These include railings, gates, finials, window-bars, ornamental hinges, as seen on the old cathedrals, lock-work, fire-irons, &c. Many of the rails are cunningly bound together like coats of mail, and can be shaken like a woven fabric. The attempts to reproduce these in cast iron are always failures. What clumsy and hideous shapes in this material meet the eye in any American city and at every step.

First. The process is unsuitable to the end.

Secondly. It seems as though the few art-loving architects whom we have in America had renounced in despair the attempts to produce good results in such a stubborn material.

25. We, as a nation, are still far from the point where we would be willing to take great pains without seeing a return in money. Where our pride is not directly affected, we are still too apt to prefer the cheap and the inferior to the expensive and durable and the excellent. The refining and inspiriting effects of the presence of beautiful forms around us

are as yet unknown to the masses of our population. If some of us do think of these things, we are but tempted to work the harder, that we may some day go to Europe and enjoy them there. And yet there seems to be no reason why we should not have this opportunity at home. We have wealth and talent, but we still lack several very important preliminaries: First of all, art-museums, the greatest of all stimuli, perhaps, to improvement in design. Then we have none of the rich antiquarian remains from which foreign artists draw their inspiration. A good many of our young men every year go abroad and bring back much that is useful as the result of their art-studies in France and in Italy; but art, and especially architecture, does not as yet receive from us that thorough study that we devote to the business-affairs of life. These young architects generally lack the long office-training and apprenticeship which go to render the designs of the French and the English so varied and so rich.

The exhibition of the drawings of the art-students of Germany alone filled large buildings at Vienna; and their beauty and the care devoted to their execution attracted the admiration of all nations. Our own display was meager in the extreme and was in the worst of taste. May the Government foster the growth of art among us and aid us to rival these people.

A great deal could be effected by giving the erection of our public buildings to the most competent architects and sculptors that the country affords. These would then serve as a school for the people and would keep conspicuously before their eyes a high model of excellence.

If the plans of our post-offices and other Government buildings had emanated from the brain of a Hunt or an Upjohn how different might have been the result.

The modern revival in art in England can almost be said to have taken its commencement from the erection of the Parliament-houses in London. Not only did architects there find a model, but schools of joiners and stone-carvers were formed, whose skill is conspicuous in the great buildings of Manchester, the new law-courts of London, and the numerous town-halls arising in all parts of the country. This matter, however, is leading us away from the immediate discussion of iron, and we will come back to it at a later period in this report.

26. Galvanized iron as used by us for roofing-purposes is unknown abroad, and would be considered too coarse a material for fine buildings. Zinc and lead are used for this purpose there in modern structures, while the traveler in Austria is struck by the numerous copper-covered roofs of the old churches, which, after one or more centuries of wear, remain in good condition. Tin I have never seen used for roofing-purposes in Europe.

27. There were several buildings of corrugated iron on the exhibition-grounds. This substance is nailed, as with us, upon a wooden frame, and is one of the most dangerous materials for spreading conflagration

known. It easily becomes heated red-rot, and sets off the wood in contact with it like tinder. These buildings are also very poor non-conductors of heat and cold, and consequently are almost uninhabitable in summer or winter. The advantage of setting up a wooden frame and covering it with iron, when wood can also be obtained for the exterior, is not easily seen. The only advantage claimed for these buildings is their portability.

CHAPTER III.

STONE AND WOOD.

CARRARA MARBLE; AMERICAN AND FOREIGN STONE; BEDDING-STONE; STONE STAIRWAYS; VIENNESE WOODS; PARQUETRY; CARPENTRY; FRAMING; FLOOR-SCAFFOLDING; PARTITION-WALLS; WOOD IN INTERIORS.

28. STONE.—In treating of this material, the field is so extended and the different qualities vary so greatly, even when taken from the same quarry, that these remarks must necessarily be very general. In fact, the object in speaking of building-materials has been, not to describe each sort with minuteness, but to call attention to a few important facts which do not as yet seem to be appreciated in America. Some things we know almost nothing about, and a report dealing with particulars would be out of place.

In England, terra cotta and ornamental wrought iron have been used in various forms for many years, and the manufacturers are naturally anxious to know of every development and advance. We have not yet reached this point, and such elaborate compilations as the English reports would excite but little interest among us.

In passing through the north of Italy a day was devoted to the inspection of the marble-quarries of Carrara. The sight is a wonderful one. As far as the eye can reach, in all directions, the hill-sides and the stretches of level ground are white with fragments of marble. Every instant the explosion of a mine is heard in one direction or another, and a constant succession of heavy wagons, drawn each by several yoke of oxen, passes along a deeply-rutted road, dragging huge blocks of marble to the workshops.

Passing through the town itself, one finds, in almost every building, workmen occupied in cutting and carving these blocks.

The writer visited many of these buildings, and entered into conversation with the men. Some were working upon capitals of columns, others upon monumental work for cemeteries. On inquiry, it appeared that a very large percentage of the work was being prepared for shipment to America. After leaving Carrara, in a railway-compartment with a very communicative Italian, much information was obtained about the quarries. He stated that there were several varieties of marble: one for building-purposes; a second used for ordinary sculpture; and, finally, an exquisitely fine-grained stone, that was unsurpassed for statuary. "But," said he, "you are certainly an American," and he at once recommenced conversation in English, and stated that he had lived some

ten years at Brattleborough, Vt., where he had worked as an assistant in Mr. Meade's studio. There, by a strange coincidence, we had met years before, and he soon recalled the occasion. The most important fact gathered from him was that our Vermont marble is superior to the Italian for building-purposes.

29. The point which we wish to make is that we should do well to profit by European experience, and should turn our attention from flinty granite to softer stone. The finest public buildings in Italy are of marble. In France, general use is made of the yellow Caen stone, which is also a limestone, while the peculiarities of the geological formation call for a more extended use of brick in Prussia, Holland, and England. Nowhere, except in America, is cut granite used in mass for building-purposes. Our climate is such that marble stands very well without discoloration if one may judge from the specimens in New York.

30. A point which we are too apt to neglect in the use of stone is the necessity of placing it on its bed-surface, or with its strata horizontal. The brown free-stone so common in our cities has a well-defined stratification, and, as surely as the layers are placed vertically, the rain and frost enter the stone and split it. Thus a heavy cornice was gradually sliced off and finally entirely disappeared, in New York, and careful inspection of almost any brown-stone front will discover indications of the neglect of this precaution. This matter is so important for the safety of pedestrians that it would be well to notice it in our building-acts.

31. Stone-stairways are found in all Vienna buildings, a stringent law requiring fire-proof communication between attics and cellars. The steps are made of single blocks of stone, built in generally at one end only in the masonry. The use of cement-blocks for this purpose has already been referred to, but the favorite material is limestone or marble. These stairways are furnished with iron or stone balusters; stone-passages communicate with them, and the whole is built in a masonry-well. The sky-lights opening into them are iron-framed, and, in fact, this is, as it should be, the most substantial and fire-proof portion of every building. In theaters, where large throngs of people are upon a stairway at the same moment, a somewhat different plan is followed. An ascending vault is sprung between two stout masonry-walls and the stone-steps are supported by this. It is hardly conceivable that a fire could prevent the safe exit of an audience when these precautions and various others connected with the illumination and stage-machinery are taken. It would be desirable to introduce such stairways into our large hotels and factories as well. Nor could, in this case, iron be substituted. If cast iron were used, it is subject to the disadvantages described under that head above, and wrought iron, while less substantial, is probably fully as expensive as masonry.

32. WOODS.—The woods used in Vienna for internal finish are marked by a finer grain than our black walnut and ash. Some of the former

wood was exhibited; but it was declared by the native joiners to be too coarse for neat work. To an eye accustomed to the delicate gradations of color of much of the foreign decorations, the contrast of black walnut with white plastering is very harsh, nor does it harmonize with ash or oak alone. Paneling of ash in a black-walnut frame with cherry-wood moldings forms a much pleasanter combination. Our butternut is as pleasing as any of the ordinary foreign varieties.

33. Very elaborate exhibitions of parquet inlaid floorings were made by Hungarian and Austrian firms. These do not consist, as with us, of a quarter-inch of veneering, but are an inch and a half of solid wood. Some of the combinations were very pleasing.

For a traveler wishing to study what can be done in the way of wainscoting, paneled ceilings, and inlaid woods, the writer would recommend a visit to Alnwick castle, the seat of the Duke of Northumberland, between York, England, and Edinburgh, whence Lord Percy went out to the battle of Chevy Chase.

34. The late duke imported some thirty Italian wood-carvers from Rome and Sienna, and employed them for nine years, in connection with a host of native workmen, in refitting the interior of the castle. Viewing it externally, one would not dream of what the building contains; but, once inside, the eye is enchanted. The work here done was the means of educating the entire neighborhood in wood-carving and joinery. Schools were formed taught by the Italian sculptors, and to-day the people of Alnwick number among them many of the most skillful wood-carvers of Europe. Our Government, or some of our rich private citizens, might undertake the same thing. We are too far advanced to-day to look upon these matters provincially. Much has been effected in England by the liberality of the rich in throwing open their picture-galleries and private collections to the public. The attempt to improve them in their handicrafts would be a step further. In these dull times, anything that can set idle hands at work cannot but be beneficial to the country. It seems incredible that strong men willing to labor should go hungry while capital lies stagnant. By all means let us study the result of foreign experience and profit by it.

35. Carpentry in Austria and in France is by no means as far advanced as with us. The vast quantity of wood growing upon our continent has given a great development to this branch of industry; and in our wooden bridges and other constructions we are quite the equals, if not the superiors, of foreign nations.

36. Framed buildings are not so common abroad as with us; they are to be found almost nowhere except in Sweden and Switzerland. A common form of construction is a frame-work filled in with brick, showing the timbers between the latter. This is called in England half-timbered work. There were several very tasteful structures of this sort on the exhibition-grounds. Among them was one built by the Prince of Schwarzenberg to contain specimens of the products of his vast domains.

The timbers were in this case champfered, arranged in regular truss-work patterns, and painted a burned sienna color, which contrasts very neatly with brick. These buildings are so common abroad that I am surprised not to have seen more of them in this country.

37. Floors are built with heavier timber than with us. In Vienna, the ordinary depth of the principal rooms in dwellings is 22 feet; and, for this span, beams of 8 inches by 6 are used; these support joists, upon which the flooring is nailed. The distance apart of the main timbers is 2½ feet. Very often boarding is nailed to their lower side and the spaces between them then filled with old mortar, plaster, brick-dust, or some similar incombustible substance, to a couple of inches above their upper surface. In this mass the joists are imbedded.

Sometimes a second series of timbers 3 by 4 inches in size are placed below this flooring and built in separately from it. These receive the laths and plastering and the stucco-work. Such ceilings cannot be subject to any shock given the floor above, and the plaster does not crack upon them. They are also nearly sound-proof and fire-proof.

Heavier timbers still are used for the attic flooring, half trees being often pinned together side by side over the whole extent, and above all is laid a brick pavement.

The law further requires that the masonry walls shall extend 6 inches at least above this pavement before receiving the plate for the roof-timbers.

38. The scaffoldings are much more substantial than with us; perhaps we might think unnecessarily so. Foreign carpenters depend very little upon nails in any of their work, but prefer to substitute pins of oak and heavy iron clamps.

Nor is one or two inch stuff at all common. Theoretically, a joist measuring 12 inches by 2 is much better to support flooring than one measuring 9 by 3, but the former has a tendency to yield laterally which the latter has to a less extent, even where bridging is used at frequent intervals. We reach excessive height when we attempt to construct a truss 50 feet in span entirely of plank, except the collar-pieces, which are of board. Something of this sort, of equal span, having a rise of only 2 or 3 feet and united only with ten-penny nails, was noticed in the Paine memorial building in Boston. This truss is said to have so unpleasantly affected the inspector of public buildings in that city that he ordered its removal. This is certainly a step in the right direction.

39. An important provision in Vienna against the spread of fire is the substitution of brick for wooden partition walls. It is astonishing to glance at the interior of some of our great buildings—in which cast-iron columns and fronts are used—during their erection. The inside seems literally full of wood; ceilings, floors, and walls, before plastering, present an enormous expanse of this material, here used in the worst possible combination.

In the great fire at Boston, the destruction of such buildings was the

work of only a few instants. The iron columns became red hot, bent and gave way, and the roof and upper stories came toppling down in a blazing mass, endangering the lives of firemen and all in the vicinity.

Such places are tinder-boxes and deserve the attention of legislators. It is to be hoped that the history of Chicago and Boston will not have to be repeated before we learn wisdom.

However, several firms in our country are manufacturing blocks of cheap material well calculated to serve for fire-proof partition-walls; and the frequent occurrence of brick-vaulted ceilings is very inspiriting. Still better would be the introduction of thicker walls, capable of sustaining vaults built of masonry and without the use of iron. In Vienna, passages are frequently covered in this way, and in the music-hall of that city all the rooms of the lower story are covered by vaults sprung from wall to wall. Some of these are cylindrical; others are segments of spheres or domes, and are made of hollow brick. Our building acts are certainly improving, but they are still far from perfect.

CHAPTER IV.

ARCHITECTURAL ARRANGEMENTS; SANITARY PRECAUTIONS.

PECULIAR TYPES; RAILWAY-STATIONS; VIENNA OPERA-HOUSE; DEFECTS OF AMERICAN PRACTICE; DRAINAGE; MILANESE ARCADE; EXCHANGE AT BRUSSELS; LOCATION; EXHIBITION-BUILDINGS; LANDSCAPE-GARDENING; DEFECTS OF AMERICAN CHURCH-ARCHITECTURE; CULTIVATION; TRAINING.

40. Many foreign cities present forms of building which are unknown here. Such are the great glazed galleries or passages of Milan and Brussels. Hotels and public buildings are also constructed around large interior glass-covered courts, reached generally by a carriage-way.

41. We have as yet done little in the way of railway-stations that will bear any comparison with those of any of the foreign capitals. Probably the finest thing of this sort in America, in comfort, convenience, and taste, is the new Providence R. R. depot in Boston. It is closely modeled after some of the best French and English stations. As a nation, we hope some day to do a great deal that is original and good in the way of architecture, but at present our only hope is to study and utilize the patterns given us by European experience. Experience alone can demonstrate what is useful, and generally what is pleasing. And this being the thing which we especially lack, the most rational course for us to pursue is to study it where its effects and results are stored up for us.

42. Many elaborate models in plaster of paris of the most important buildings either erecting, projected, or recently completed in different parts of Europe were conspicuous objects in different portions of the Vienna Exhibition. One large department was filled with Austrian plans and models.

43. Building activity in Vienna, as well as in Pesth and the capitals of the other Austrian provinces, has of late years been intense. Carried to too great an excess, it was the cause of the recent money-panic in Vienna. There are, at present, in course of erection in that city an academy of the fine arts, a town-hall of 400 feet front, two large museums, a parliament house, and a building of vast extent to contain all the faculties of the university. The general plan of all of these, with one exception, is similar. One or more large central courts afford light to the interior rooms, and are admirably fitted for the location of court-rooms and for lecture-halls, where quiet is a desideratum. When these courts are of large size, say 60 feet square, the sunlight finds direct access to many portions of the building from which it is excluded with us.

44. The styles of these buildings are all different. The renaissance, Gothic, Greek, and Roman architectures are all to be represented in their

purity, and each building is intrusted to a master who has made one of these schools his specialty. Some $20,000,000, at the lowest estimate, will be required for their completion.

45. Of the buildings already erected in Vienna, the Opera-House above all others deserves especial notice. After the new Paris Opera-House, this is the first structure of the kind in the world. The taste and magnificence of the interior are admirable, and the most ample precautions are taken to guard againt fire. Numerous stone stairways lead to all portions of the house, and vaulted passages give access to these. The stage is surrounded by masonry, with tiers of stone and brick galleries from which numerous streams of water can be directed at a moment's notice upon the scenery and scaffoldings. An ample *foyer* offers an agreeable promenade to the audience during the intermissions, while the comfort and roominess of the seats deserve all praise. Here, something has been done to please the eye and to elevate and refine the taste of the public, who are not merely treated as individuals from whom money is to be extracted. The arrangements for ventilation and the preservation of an equable temperature are also excellent; and at the close of a performance the auditorium is not sensibly warmer than at the commencement.

For this purpose, steam-engines are employed pumping in fresh air and drawing off that which is vitiated as fast as its vitality is exhausted.

46. Where the government undertakes the erection of these buildings for public purposes, the best results can be much more readily attained than where, as with us, they are left to private enterprise. Yet even in our country restrictions and wise laws can be productive of much good. Precautions against the spread of fire, regard for the safety of the public in the condemnation of improper forms of construction, and the introduction of sanitary measures to insure cleanliness and the proper access of sun-light and air are all desirable.

47. We are very careless in America about the location of water-closets in buildings. These are to be seen in many hotels and theaters far in the interior, removed from all possibility of ventilation. The building-laws of Vienna may teach us a lesson in this respect. All rooms devoted to this purpose must have a sufficient number of windows opening, not into other apartments, but directly into the outer air.

48. We have also much to learn in the matter of drainage. Our cess-pools, loosely built without mortar, allow all liquids to filter directly into the surrounding soil, where, after this excellent disinfectant has become saturated, they distribute their emanations and pollute all springs and wells for many yards around, causing typhoid fever and epidemics. The proper substitute for this is a closely-cemented receptacle which should be frequently emptied.

As yet we have found this latter expedient too expensive and troublesome, and it looks as if a plague might be necessary to bring us to our senses.

The waste of useful fertilizing matter it is hardly within my province to treat; but a great deal in this respect can be learned of the Chinese, whose older civilization has taught them economy in this important matter. English firms are already bidding for the sewage of St. Petersburg, and other cities, which they will deodorize and probably find as profitable as guano.

49. But returning to the architectural models: First was noticeable in the rotunda the glass-covered passage of Milan. This is the largest and finest in the world, and can be easily described as a broad, handsome street of fine buildings, of equal height, from whose cornices iron girders, stretching across the way, carry a glass roof. The lower stories are shops and coffee-houses, and the whole forms an agreeable retreat in rainy weather for promenaders and for ladies intent on shopping. It is not accessible to carriages, and the great expanse of its tessellated pavement affords room for a large number of pedestrians. It abounds in pleasing architectural decoration, a rich play of color, sculpture, and painting.

50. Another model in the rotunda was of the new Exchange at Brussels, one of the finest modern buildings of Europe, and the first of its class in existence. The building itself was visited at a later period, and the writer can attest the magnificence of its inner fittings and its commodiousness and accessibility by various entrances, standing, as it does, disengaged in the center of a square.

51. This position is certainly the proper one for all important buildings. Much of the imposing appearance of Paris is owing to the skillful location of its finest structures, at the junction of several streets. A view is thus gained of their proportions from various points, and they are easily-discoverable and conspicuous landmarks. The custom of laying out our American cities like the squares of a checker-board, as in New York and Philadelphia, renders this impossible, at present, with us. To view our churches and finest structures it is necessary to cross the street and raise the head painfully, while in the narrower streets their architectural effect is entirely lost. How imposing is the approach to the Madeleine, to the Gare du Nord, or to the new Opera-House in Paris; and the Arc de Triomphe arrests the eye on entering any one of the numerous avenues which radiate, star-like, from it as a center.

52. The Viennese models included the buildings before referred to, and must have been prepared at great expense. The new Town-Hall by the German leader of gothic architecture, Mr. Schmidt, is in many respects an originally-conceived structure, and is familiar to the readers of the London Architect and Building News. It is supposed that ten years will be occupied in building it. One of the most pleasing effects of the architecture of Vienna arises from the uniformity in height of the buildings on the principal streets, and their wide fronts, presenting, sometimes for 200 feet, the same unbroken lines of cornices and windows. Adjoining buildings vary sufficiently in architectural detail to avoid

monotony, but an attempt is generally made to carry certain important lines across an entire block. There are thus a majesty and repose in her great thoroughfares that are entirely lacking in such districts as, for instance, the rebuilt portion of burned Boston. There a thousand varieties of taste have been allowed to run riot, and in general our tendency is to attract attention by giving to our particular building a greater height than its surroundings or by varying its architecture and its material as much as possible from the ordinary style. Thus have arisen those strange productions of wild fancy, the Tribune and the Western Union Telegraph building, New York.

53. A little farther down, on the east side of Broadway, the Equitable Insurance Company, formerly possessing one of the most dignified and imposing fronts of New York, is now emulating these rivals by the addition of an abnormal roof, containing a ninth and a tenth story, while the harmony of the design is impaired by a change of the architect in the midst of the work. This latter building, however, is a fine instance of what American enterprise can achieve when it is for its interest to put forth its powers. Six elevators mount to the height of 150 feet, making the upper stories as accessible as the ground-floor, while the fine ranges of offices, though commanding very large rents, are all occupied, and pay a handsome return on the capital expended. No business-building in Europe can compare with this in convenience and comfort, nor so admirably fulfils its design. It is also satisfactory to know that it is as nearly fire-proof as it can be, having an iron roof, stone stairways, and masonry elevator-wells built on the exterior, as the law requires.

54. The buildings upon the Exhibition-grounds will be so fully described in special reports that nothing need be said of them here, except that the plan was not as well adapted as that in Paris, in 1867, for viewing the products of the different countries in groups. Some of the entrances were very imposing; but, from the great height to which they were carried, they completely overtowered the buildings themselves, and did not seem to be organic parts of them. The rotunda, designed by J. Scott Russell, of London, was a grand achievement of engineering, and will doubtless be fully described in the proper place.

55. One of the most pleasing features of the whole exhibition was the landscape-gardening and general laying out of the grounds. Avenues lined with shade-trees led to the main entrances, and frequent fountains cooled the air and pleased the eye. Great stretches of lawn and flower-beds added to the park-like effect of the whole.

56. The writer has probably shown, thus far in this report, that we have a great deal to learn from the other side of the water. We doubtless teach the world much that is valuable by many of our productions. Our suspension-bridges and many of our engineering achievements are warmly praised abroad, but there is no doubt that in artistic effect we are yet far in the rear. Before closing this paper the writer wishes to refer to a few other points in building-matters in this country, and to com-

pare our efforts with similar foreign ones. The point to be made is that neither the public nor our professional men are as yet sufficiently trained to creditably meet the problems before us.

Of late years a large number of churches have been erected in our rapidly-growing cities. The new region upon the Back Bay district in Boston contains many of these structures, and in New York the upper parts of Fifth and Madison avenues have offered locations for a corresponding number. It is extraordinary how few of these will bear criticism. In some the architects have been so engrossed in their studies of frescoing and colored glass that they have forgotten utility. The clergyman's voice is often inaudible even in the front pews, and either almost total darkness or a dazzling flood of light interferes with the comfort of the congregation.

The matter of acoustics is one that of late years has made but little advance, but certainly such great defects in hearing-properties as are present in some of our new edifices could have been avoided. M. Garnier, the architect of the new Opera House in Paris, has written a very interesting pamphlet on the subject of theaters. He maintains that it is always possible to predict before the erection of a building whether it will be acoustically good or bad. As regards the architectural appearance of these churches, a tendency is noticeable, as in the secular structures I have spoken of above, to strive after novelty of form and effect. Now all critics agree that what is new has always been of slow growth, and that whenever an attempt is made to strike out abruptly into a new path the result is a failure.

57. A great deal that is old in Europe is new to us; and if novelty is our object, we should do better to study this than to attempt to create. In design there is no doubt that whatever is produced owes its origin, in great part, to the remembrance of something seen before. Let us then look at what is good in training our hand and eye, rather than attempt to rake up from the store-houses of our memory what we have imbibed we know not how or where.

58. Again, we are much inclined, as a people, to set at work with all energy, before the matter in hand has received the proper consideration. Then, when all is completed, we often wish that we had gone to work in an entirely different manner. Thus, the Back Bay district of Boston has been rapidly covered with palatial residences, at the expense of many millions of dollars, until, to-day, no similar tract can be found in the entire world which can exhibit an equal number of people living in luxury, with all their surroundings rich and in keeping. But suddenly—only fifteen years since the whole was a tract of water—the owners of these residences regret that the bay was not filled in to a height of several additional feet. Drainage will probably have to be assisted by steam-pumps; while some predict that, from the unhealthy condition of the district, the whole must be raised or ultimately abandoned as a dwelling-place.

Again, after the fire in the same city, many of the streets were widened, but only to a slight extent. Washington street, the principal thoroughfare, was increased in width at certain points by 3 or 4 inches. The day will soon come when we shall wish that it had been widened by a great many more feet.

In all these matters some more efficient supervision of the Government is called for. We have inspectors of buildings; but their number appears insufficient or they are not properly trained for their positions. A case illustrating in a marked manner this truth is that of Dr. Hall's church, on Fifth avenue, New York. This building had nearly reached completion when the parish was informed that the main front projected beyond the sidewalk-line by a short distance and that the whole must be pulled down. This could only have occurred through the negligence of the surveyor, of the inspector, or of the architect. The inspector was, in any case, evidently to blame. In a similar case in Vienna, where a company engaged in building a new theater had transgressed in the same way, the matter was settled for a small fine, the government tacitly acknowledging that it was itself to blame for not arresting the work at an earlier stage.

59. We have before referred to the part played by the rich, in England and elsewhere, in improving the taste of the people. Foreign governments have considered it as necessary to establish academies of the fine arts and art-museums as military and naval schools. In the former institutions the young are taught painting, sculpture, architecture, and engraving; and from the study of the museums they receive the inspiration necessary for the production of works of merit. Libraries containing standard works on art, and the numerous art-periodicals published in London, Paris, Berlin, Vienna, and Stuttgardt, are connected with them. Here, also, photographs of buildings, paintings, and engravings are to be found, and are open to the inspection of the student and of the public. Lectures are delivered at frequent intervals, and prizes are offered to the students, many of them being in the form of scholarships, enabling them to travel for several years in Italy and Greece. The most prominent graduates of these institutions are intrusted with governmental works, and no worker, whatever be his position, is expected to undertake any labor without having previously received the proper training. Still more, in the advancement of art, England and Germany have sent workmen to Italy to model in plaster the entire fronts of the most famous buildings of antiquity, in order to still further enrich their museums. In the South Kensington Museum, at London, the results of such work upon the front of the famous Certosa, near Pavia, are to be seen reproduced in terra cotta. We have no antique remains in America; but we can certainly supply their place in this manner. Thus artists are educated abroad and are qualified to produce monuments which will command the admiration of posterity.

How interesting is a visit to Rouen or Chartres, in France, or to any

of the old capitals of Italy. The eye is enchanted by beauty and richness of form and color on every side; but who is charmed or inspired by a stay in our Washington, after the novelty of the impression produced by the great size and cost of our Government structures has passed away? It is hard for those of us who have passed all our lives in America to picture what might be done in these matters; and yet few of us fail to be delighted on viewing the great works of the Old World. There the whole atmosphere changes. Money-getting is lowered to a less prominent position in every-day life. The intense hurry which wears us out and leads us constantly to overstep our mark is no longer to be noticed. Mature deliberation precedes every important movement. In art, the attempt is made to have a reason and an object for every step taken. Meaningless ornamentation is avoided and everything fulfills some end. Our school lies open to us. Let us first take in all that our masters can teach us; and then, and not till then, let us attempt to improve upon them.

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C.

WOOD-INDUSTRIES.

N. M. LOWE.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

WOOD-INDUSTRIES.

BY

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MEMBER OF THE ARTISAN COMMISSION OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

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WOOD-INDUSTRIES.

CHAPTER I.

AMERICAN EXHIBITS AND METHODS.

THE AMERICAN EXHIBIT; AWARDS; CARRIAGE-WHEELS; FURNITURE; WOOD-WORKING MACHINERY; CARRIAGES; MOSAICS; EFFECTS OF HYGROSCOPIC CHANGES DOUBLE WINDOWS IN COLD CLIMATES; SEASONING.

1. The American exhibit in Group VIII was extremely deficient. Our people work wood with as great, if not greater, facility than those of any other country, if we leave out of consideration the finer artistic carving, inlaying, and mosaics. It should, however, be remembered that we had several large and excellent exhibits of wood-work that were ruled out of this group, under the regulation that no article could be entered for a premium in two groups. There was the school-house with its furniture, and school-furniture, in considerable variety, in the educational department. They were excellent of their kind. In the exhibits of other countries, these were classed in Group VIII. Then, there were musical instruments, consisting of two very large exhibits of cabinet-organs, the cabinet-work of one of which, at least—that of Messrs. Mason & Hamlin, of Boston—would have taken an award for its good workmanship and fine designs, as well as its solidity of construction—which latter was abundantly shown by the manner in which it had withstood changes of climate—if it were not for the other reasons given. Both houses having exhibits in this line benefited by the exhibition in the receipt of orders. Some good work was shown in the piano-forte cases from New York, contributed by Steck, which fully sustained the reputation of fine American wood-work.

Premiums were awarded to the following American exhibitors: George W. Howe, of Cleveland, Ohio, vent and bung, diploma; Pope Brothers & Krugman, of Cincinnati, Ohio, lacquered gilt and black-walnut moldings, medal of progress; John G. Davis, of Philadelphia, Pa., carriage-wheels and stock, medal for good taste; Wheeler and Wilson Cabinet Company, of Indianapolis, Ind., veneers, medal of progress; Charles Weeks & Co., of New York City, wheels, medal of progress; United States gun-stocks, Springfield Armory, medal of progress; Woodburn Savern Wheel Company, of Indianapolis, Ind., wheels, medal of progress; A. S. Parks, of Winchendon, Mass., pails, medal of progress; B. F. Sturtevant, of Boston, Mass., machine peg-wood, medal for good taste.

It will be seen, on examination, that America received more medals

in this group than were awarded to England; the latter being only ahead in having one diploma of honor.

2. The large preponderance in exhibits of wheels is explained by the fact that wheels were shipped largely from the United States to all parts of Europe, even to Vienna. We do not know to what extent the trade in American wheels was increased by the exhibition; but they were greatly admired by the jury, and our "beautiful hickory wheels" were frequently alluded to by them. The American carriage-wheel is a production which we can justly pride ourselves upon. It is so constructed as to combine a maximum of strength with a minimum of weight. This result is obtained, in a measure, by the wood employed, and by the manner of using it, the bent rim, and the setting of the spokes in the hub in such a way as to present a plane disk instead of a concave wheel, as in the case of all European wheels. Our spokes are either set so as to present a large base of support at the hub, or they are supported by iron flanges upon their sides. To illustrate the superiority of the American over the European wheel, it may be shown that, while the American wheel can be fixed upon an axle which will allow it to run free in a vertical position, the dishing European wheel must be set under, or "*struck*," in order to bring its rim in contact with the earth vertically under the center of the hub, in which position it can never run so free as if made to run on a perfectly horizontal axis. This may be a small matter in light wheels with narrow rims; but with wide rims, like those exhibited in the English Agricultural Hall, where wide-rimmed wheels were shown that were made quite conical, the result would be, in draught, a tendency in each wheel to roll off outward in a circle, and considerable power would have to be constantly exerted to keep them in a straight line. A remarkable instance was shown in an English steam-roller and road-engine, where the forward roller consisted of two conical sections placed upon an axle, the large ends abutting, so as to make a straight line at the bottom and open at the top in the center, to receive the transom-bolt or vertical shaft used to steer by. It can readily be conceived that it would take a considerable force to make these two conical cylinders, each 2½ feet long, roll in a straight line. Just imagine the success of any effort to make one of these conic sections roll otherwise than in a circle, without a dragging force arising somewhere.

3. It is to be regretted that some of our best furniture-makers were not represented. Some, it is true, made entries, but their goods were never shipped, it seeming to require but little to discourage them when there was no hope of gaining trade.

The wood-working machinery and tools in the United States section were excellent, if not numerous. Mr. Park, of Winchendon, Mass., exhibited a full set of pail-making machinery (made by B. D. Whitney, of the same place) in full operation at first; but from some misunderstanding their operation was afterward suspended, much to our regret.

The articles here produced were eagerly sought after for the museums in different parts of Europe. The water-pail of the continent is flat and high, and is carried upon the back with shoulder-straps, and has a cover to keep it from slopping over. Bailey's planes and other tools were also eagerly sought after for the technological schools. Two English firms, as agents for American manufacturers, exhibited in the department of the United States a large collection of American axes, scythes, and other tools, showing that the direction of trade in this line has been reversed. Mr. Whitney, of Winchendon, Mass., made the principal display of wood-working machinery; it was declared by a large Austrian manufacturer "fit to kiss," so great was his admiration of it. Many requests were made to be allowed to make drawings of the different machines, which were all met in a commendable spirit by Mr. Whitney, who gave all perfect liberty to make such drawings as they pleased; feeling, no doubt, that in any event he could compete with their best skill in manufacturing.

A light open buggy, from California, was shown, which was beautitifully finished in the natural wood, and ornamented with inlay, in lines of mosaic, on the black-walnut body. Two other attempts were made at inlaid work: one was in cabinet-organs, with only moderate success, and at a cost entirely disproportionate to the results obtained; the other was a lady's dressing and sewing case in fine marquetry, with fair success, but in such bad taste as to gain no award. The designs on the latter were of a patriotic character, mingled with the emblems of war, which would have been more appropriate for a shooting-case. We may expect to make little progress in the production of articles of taste and fancy in wood until we learn to produce the real French polish; for in no other way can such articles be finished with sufficient neatness to compete with the European makers. We are aware that the opinion prevails that this polish will not stand our climate; but the same opinion once prevailed in England. This prejudice must have been removed in that country, if we may judge by the samples of French polish exhibited in Vienna by English makers. These were really better than those produced in France.

4. We will state here some of the conclusions derived from experience and observation in the manufacture of woods. The hygroscopic character of wood is such that any change in the relative humidity of the atmosphere must act upon the manufactured article to shrink or to swell it. This is a law as fixed as that of gravitation. The question, then, is, Under what condition, as to relative humidity, should such articles be made? In Europe, the necessity of economy of heat is such that the people use the least possible amount of fuel, as may be seen by examining their porcelain stoves; and they accustom themselves to live in a temperature that is much lower than the people of our country like in their houses; the air is therefore much drier. From Russia, southward, until we reach a line where little or no artificial heat is needed for

comfort, every appliance is used to reduce the amount of fuel consumed to a minimum quantity; thick, heavy walls are made for houses; double windows are adopted, and apartments are close. The temperature of European houses and workshops being much lower than ours, the air is consequently more heavily charged with moisture. When, therefore, we import the furniture of Europe and place it in our American furnace-heated houses, where the air is exceedingly dry, there must of necessity be a change in its condition—a shrinkage must occur. From personal observation, we should say that Boston houses in the winter-season average as low as 25 per cent. of saturation, and in the coldest weather it is often as low as 15 per cent. We have seen a parlor in Boston at a temperature of 85°, with but 15 per cent. moisture in its air, and young and healthy persons therein complaining of the cold and calling for more heat.

5. This brings up a very important subject, which we very much regret we cannot here make more than a passing allusion to, and that is the necessity in our northern country of adopting a system of double windows for our dwelling-houses. We should be astonished if our inquiries in this direction led us to the discovery that 75 per cent. of the heat of our rooms, which is lost by our single windows in the winter-season, could be saved if these windows were provided with double sashes. During the cold weather, there will always be found, no matter how tightly or closely the sashes are fitted and protected with weather-strips, a draught of cold air falling downward. This arises from the contact of the heated air with the cold glass, which renders the air cooler and heavier, and causes it to fall. The air, at the same time, parts with a considerable proportion of its moisture by condensation upon the glass. The cold air thus formed falls to the floor, forming a layer of cold air, which surrounds the feet and legs, while the upper part of the body is enveloped in overheated air. The layers of cold and warm air in an apartment *will not mix*. The warm air will not descend, and the cold air cannot go upward, except the one is deprived of its heat by radiation, and the other receives its heat by actual contact with a heated surface. This radical difference in the upper and lower strata of atmosphere of the rooms, in which our people live during the cold season, is the prolific cause of most of the throat and lung diseases with which they are afflicted. Double windows to our houses, therefore, would not only be a great economy as to fuel, but highly conducive to human longevity.

6. We have seen the cabinet-maker in Vienna working in a damp cellar making articles of furniture. We have seen, in Florence, men making fine carvings and the finest of wood-work in damp, vaulted rooms, under an old cathedral. Now, the question naturally occurs, why should not both the makers and consumers of wood-work know a little more of the laws of nature, and of the relative conditions of the air they work in and that in which their customers live, so that such

stupid mistakes as have been made shall not be again made in the future? And, again, should not our common schools teach a little more of hygrometry, and, if necessary, a little less of sidereal astronomy?

The principle here noted could be seen illustrated in the Palace of Industry at Vienna, where the products of all countries were collected and where were plainly visible the effects of difference in the condition of the air from that of the atmosphere of the places in which they were made. An elegant inlaid table was shown, the foundation of which had become warped, showing through the veneering that the boards of which it was made were sawed from small trees without reference to the grain. As a consequence, the outline of every board employed was visible through the fine marquetry.

7. There is still much to be learned in the treatment of timber, and its conversion into shapes for use in the finer and more costly work of cabinet-making. The old-fashioned way of sawing for such purposes has been proved to be entirely wrong. Trees are made up of a number of alternate layers of growth, forming rings around the center; each ring representing a year's growth. Besides these rings, there are radial lines running from the center outward, like the spokes of a wheel, which are known as medullary rays. Boards sawed from a green log contain a large amount of moisture, which, on exposure to the air, they readily part with, losing bulk by shrinking. While this fact is well known, the direction of the line of such shrinkage is not quite so familiar. It may be thus explained: Wood being a fibrous substance, with bundles of such fibers placed lengthwise, in shrinking these fold and crowd in upon each other, and the whole board visibly contracts. The important point to be noted here is that the direction of shrinkage is invariably at right angles with the radial medullary rays. The best way, therefore, to saw a log for lumber for furniture, or other nice work, is from the circumference to the center, in the way, to use a familar illustration, that clapboards are now sawed out. Boards sawed in this way cannot warp. The shrinkage is from the surface inward, and evenly along the surface. A knowledge of this fact may enable wood-workers generally to make articles that will stand any climate different from their own, and no other method will serve in its stead.

In our own country, there is still a great deal of ignorance in regard to the proper means of drying lumber by artificial heat. It is so common as to have become a usage to put in wet lumber at one end of the dry-house and take out seasoned lumber at the other end, that we cannot wonder at the general want of confidence in this system, or rather want of system, in drying lumber. There are those who, in addition to the absurd practice mentioned, utterly ignore the necessity of ventilation in their dry-houses, while others have their ventilators in the roof. This is all wrong. The dry-house, in the first place, should be divided into compartments and ventilated at the bottom, so as to utilize the heat and equalize the process of drying. The progress of this work of

drying could be easily measured by a hygrometer, and the process concluded when the degree reached was equal to its probable exposure, which, as we have seen, in a furnace-heated house may be equal to 20 per cent. of saturation.

8. In connection with this, it may be stated that a new method of seasoning has been perfected, which is so simple and effective that it must become universal where the requisite conditions can be obtained. This new method is the invention of Mr. George Woods, of Cambridge, Mass., and may be thus described: The room to be used is made tight, and is heated best by steam, though it can be otherwise heated. One side of the room is made into a condenser by coils of pipes through which a stream of cold water circulates continuously, cooling their surface, and keeping it so much below the temperature of the room that the moisture, which is rapidly drawn from the wet lumber by heat, is as quickly condensed. Underneath is a gutter, into which the vapor thus condensed falls and is carried off in the shape of water. If the temperature of these condensing pipes can be kept at say 40° Fahrenheit, and that of the atmosphere be raised to 90°, it will not require a long time to reach a degree of 20 per cent. of saturation, when the work of drying is thoroughly completed. As the process described is the very best yet known, and as it leaves literally no room for improvement in the process of lumber-drying, it has only to become known to be generally adopted.

9. Messrs. Jackson & Graham, of London, England, show the best attention to matters pertaining to the proper treatment of wood. Their works are very extensive, and will be referred to again. For the foundation of such work as is veneered, they use only San Domingo mahogany, and only such as will work with the surface in the direction of the medullary rays. At the exhibition, they showed several pieces of oak-work, in every part of which this rule was adhered to. They make dado-work, selecting their stock with the same care that a cooper would exhibit in selection for a specimen of his art.

An American merchant, with more enterprise than knowledge of the rules to be observed in cutting lumber, had sent to a Vienna maker a quantity of piano-sounding-boards stuff, which the latter declined to use, or pay for, or to tell why. The writer was called in as an expert, and saw at once that the stock was badly manufactured, especially in regard to the direction of the grain. European sounding-boards are gotten out with great care; they are always split so as to insure straight grain, and surfaces exactly correct as to the direction of the medullary ray. The mortification of the American piano-maker at Vienna would have been saved by adhering to this rule. We need to be educated to the fact that this is the most beautiful grain of wood, because most durable. There were many interesting examples of this in the wood-work of the exhibition. Proper attention to this matter would aid very much in making parquetry that would be satisfactory in our climate.

CHAPTER II.

DETAILED REPORT ON EXHIBITS.

CLASSIFICATION; BUILDING; VENEERS; PARQUETRY AND MARQUETRY; COOPERAGE; WOOD-CARVING; FURNITURE; FANCY GOODS; MACHINE-MADE ARTICLES; WILLOW-WARE; WOOD FOR MUSICAL INSTRUMENTS; CONCLUSION.

10. Having disposed of preliminary and general matters which it has been deemed necessary to treat of in this report, we will now proceed to give a detailed account of the wood-industries of the various countries as exhibited in Group VIII, together with such statistics of their extent and general character, and matters of interest as were observed or learned with reference to them, and which were of sufficient interest to be noted. The group in question was classified as follows:

1. For building purposes.
2. Veneers.
3. Parquetry and marquetry.
4. Cooperage.
5. Wood-carving.
6. Furniture.
7. Fancy goods.
8. Machine-cut articles.
9. Willow-ware.
10. Woods for musical instruments.

It would extend this report to voluminous dimensions were we to attempt to enumerate all the firms in this group and their exhibits. We will therefore only mention some of those to whom diplomas of honor and medals of progress were awarded, and some of those whose position on the jury debarred them from competition. We will take up each of the ten classes in its order.

CLASS 1.—FOR BUILDING PURPOSES.

11. The objects belonging to this class were to be seen in and around the many buildings, pavilions, and huts which surrounded the larger exhibition-buildings.

Bark & Warburg, of Goteborg, Sweden, exhibited a hunting-pavilion of peculiar construction, for which they held letters patent in their own country. They were reputed to be doing an extensive domestic and export business in sashes, doors, blinds, and shingles. Their capacity for making doors was stated to be 1,000 per week. Their foreign markets are in North Germany, Belgium, France, and England.

The pavilion used as a Swedish restaurant was constructed by A. O. Haneborg, of Christiania, Norway. This was a very pretty frame-building, with elaborate machine-carving in its interior.

The Parquet and Chalet Factory of Interlaken, Switzerland, contributed a Swiss frame-cottage of their own make, which was used as a school-house and as the commissioners' quarters. This was one of the best Swiss buildings exhibited.

Of shingles, there was no great variety shown; but most of the coun-

tries of Europe exhibited them, showing that, though seldom met with in the large cities, they are still in use in the country districts. In size, they are 75 centimeters (30 inches) long, 1 thick, ($\frac{4}{10}$ inch,) and 10 (4 inches) wide, and cost about 35 cents per hundred. The average price in Austria ranges from 5 to 7 florins per thousand. European shingles are usually grooved on one side and tongued on the other to fit closely. They are also split so that their surface is in the direction of the medullary ray. The Austrians have a method of preserving shingle-roofs, which should be known in this country, where so many roofs of this kind are in use, rotting away from year to year for the want of some cheap and effective method of preserving them. In Austria, after the shingles are laid, a composition of coal-tar, powdered quicklime, and fine sand is spread evenly over them like paint, and forms an excellent protection against decay. Where tar has been applied in this country, it has been found that the pyroligneous acid which it contains injures the wood; but the Austrian plan remedies this, the quicklime mixed with the tar neutralizing the acid by its alkaline properties.

The Schwarzenberg domains in Austria produce 250,000 shingles a year, and Hungary 750,000. These totals, however, will seem small beside the products of some of our American shingle-makers. In Austria, Norway, Sweden, and Russia, Gangloff's shingle-machine is in extensive use. It is used to a very limited extent in other countries.

In Norway, there were said to be 645 saw-mills, employing about 10,000 men, and usually driven by water-power. Germany produces very little wood for building purposes. The oak-forests of that country are very largely drawn upon for railway-ties; it is estimated that about one and a half millions of oak-trees were used in the construction of their railways, which require for repairs the additional sacrifice of some 150,000 of these trees annually. This drain has so enchanced the value of oak-wood as to force the authorities to look for substitutes for it in the softer woods; these are prepared to resist decay by impregnation with bichloride of mercury, and are said to answer quite well.

In the finer descriptions of house-work, the French no doubt excel. This fact was well exhibited in a door contributed by Bertrand, of Paris, which was placed in the pavilion occupied by the French commissioners. This door was elaborately carved and ornamented with wrought-iron angles and fastenings in the style of Louis XIII.

Spain and Italy, it would appear, rely mostly on other countries for their styles and matters connected with the wood-work of houses.

The flat-boats on the river Danube are made tight in their joints without the use of tar, pitch, or oakum. The joints of the planking are beveled so as to receive between them a kind of reed, which is pressed into the seam, and held there by clasp-like, double-pronged nails, which not only press the caulking-material into the seams, but keep the planks together, making them almost as strong at the joints as they are elsewhere. Such a system of securing joints in planking would reduce the necessity of excessive strength in frames of river-boats.

Class 2.—Veneers.

12. Nearly all countries were represented in this department of wood-work, but only one firm was fortunate enough to secure a medal of progress—G. C. Bartels & Sons, of Hamburg. It may be proper here to remark that, while veneers are manufactured in all the great centers of wood-furniture industry in Germany, they yet lack our system of quick-working planing-machines, which give to the work so fine an appearance.

In behalf of Austria, the Princes Schwarzenberg exhibited a fine assortment of veneers, cut to one-third inch in thickness, from all classes of Austrian forest-wood. In addition to this, the Austrian department exhibited a large number of veneers. In Vienna, there are some six or seven veneer-factories, of which that of C. Dosz is the most notable. There is also a large manufactory of veneers in Pesth, Hungary.

Switzerland must be credited with the contribution of some very fine specimens; the firm of J. Pays & Son, of Luzern, sent superior exhibits of walnut veneers.

Sweden exhibited only oak and beech veneers, which were cut in the technical factory of Kulla.

Russia produces veneers, but exhibited none.

Spain and Portugal exhibited nothing in this class. These countries look to foreign markets altogether for their veneers.

Sweden was credited with importing yearly from Germany about 150,000 pounds of veneers of the finer woods, such as mahogany and rosewood, and 80,000 pounds of oak and elm. There is a factory in Stockholm, (Ekmann's,) which is said to produce annually some 60,000 pounds of veneers in different kinds of wood.

Class 3.—Parquetry and marquetry.

13. To commence with parquetry. If the proper wood is selected and laid with due regard to the running of the grain, that is, in the direction of the medullary ray of the wood, it may overcome the difficulties experienced in our climate with this and other kinds of fine wood-work.

Tasson & Washer, of Brussels, Belgium, are undoubtedly the manufacturers of the best parquetry, and next in rank stood the Parquet and Chalet Factory of Interlaken, Switzerland.

In Austria and Hungary, there are large numbers of these factories, and there is hardly a house of recent construction that has not parquet-floors. These floors, with few exceptions, are pretty nearly all alike in design and construction. This work is very expensive if executed in rich patterns with rare woods, but oak parquetry, which is most common, costs from 10 to 14 florins, or $5 to $7, per square of 8 square feet.

Germany, as yet, produces very little parquetry, except in the southern portion of the empire. In the north, it is as yet considered an article of luxury. In France, Italy, and Belgium the same is as true as of North

Germany; only the wealthier classes availing themselves of it. The article in these countries is still very costly.

Marquetry is occasionally introduced in parquetry.

In the Royal Palace of Pesth, the floor, which had been laid many years before in parquetry of the Moorish style, in bent wood, by the Thonet Brothers, had to be repaired, owing to enlargement of some of the apartments; but the pattern was of so difficult a nature that no one would undertake the work except the Thonets, (who had discontinued this branch of their business,) who soon successfully completed it under great difficulties, having to draw upon the resources of all their factories for fragments of bent wood required.

In Austria, an industry exists which is entirely new to Americans. Two firms in Vienna manufacture inlaid-wood mosaic veneers, to be used for inlaying furniture of all descriptions, more especially for use on small tables with round or square tops. Ladies' fans are also made out of this material.

In England, the firm of John R. Clarke has factories in London and Tunbridge Wells, making elegant mosaic fancy articles. England, France, Italy, Spain, and Portugal use a great deal of marquetry in their furniture.

CLASS 4.—COOPERAGE.

14. In Switzerland, we find an industry entirely peculiar to that country. The firm of Berger Brothers, in Thal, Bern, exhibited pails, milk-vessels, churns, and apparatus for cheese-making, which were really meritorious.

Austria produces a peculiar vessel, a kind of pail, to carry water in, which is also used very considerably by women of the laboring class for carrying coal, fruit, and linen. It is intended to be carried on the back by shoulder-straps.

There were three immense butts, or vats, on exhibition, one of which held 3,000 eimer, equal to 30,000 gallons, another 25,000 gallons, and the third 20,000 gallons. They had all been sold to proprietors of large vineyards. They were perfect masterpieces of cooperage, and showed that their makers must have had extensive works. Some very fine specimens of wine and beer barrels were also shown. One exhibitor showed wine-barrels of a novel shape, being in some respects the reverse in shape of those in ordinary use, that is, concave in the center and widening toward the ends, somewhat like an hour-glass. The inventor claimed that by this shape he could save space in stowage. Karl Drexler, of Vienna, exhibited some very well finished and well constructed oval and octagon shaped barrels. There was also shown a barrel, of excellent workmanship, in which to keep wine cool. It was an expensive affair. There were also to be seen, quite a novelty in their way, Hungarian drinking-flasks and canteens, made of wood and bound with hoops.

The Germans manufacture their own beer and smaller wine barrels, in some cases, by machinery. They make in this way, however, large numbers of barrels for packing purposes—the machines used being American. Much of this class of work, however, is still done by hand.

Wooden clogs, or shoes, except in Italy and Holland, have mostly gone out of fashion, as has also wooden kitchen-ware—such as dishes, salt-boxes, and ladles—which latter are now altogether replaced by tin-ware.

There is an article of wooden ware in general use throughout Austria and Southern Germany, which may be properly mentioned here—wooden boxes, made of thin strips of machine-cut and planed wood, about one-third of an inch in thickness, bent in circular or oblong form, with rounded edges, and with bottoms and covers of the same material, well adapted for collar-boxes. Moritz Saxl, of Boskawitz, Austria, was the maker of those exhibited. The strips of wood from which these boxes were made are sold in the forest-mills of Austria and Bohemia at very low prices. The strips are often used for hoops of sieves and for drums.

Sweden exported, in the year 1871, two million pieces of oak, and seventeen million beech and other staves, of which latter class England took thirteen million, and Norway, Denmark, and Russia the remainder.

Italy, France, and Belgium showed no articles of cooperage.

Class 5.—Wood-carving.

15. Italy excelled in this, as in many other departments of art. Luigi Frullini, of Florence, and Cav. Gio. Bat. Gatti, of Rome, received the highest award for their exhibited works. The exhibits of these manufacturers were the most beautiful of their kind; the scenes and figures represented were of the highest style of art. An Italian pear-wood tablet, representing "Spring," was bought for the Museum of Edinburgh, Scotland, for 5,000 francs.

Switzerland and Austria ranked next in art-carving on wood. In Switzerland, however, wood-carving is more of a trade than an art. Small carved Swiss cottages, and articles carved in pear-wood, were the most notable.

The Austrian (Tyrol) productions were better and more pretentious; they were representations of festive scenes, Tyrolese pictures, and copies in wood of historical and other paintings.

China and Japan excel in carving, in their peculiar style, in ivory and bamboo. The art of carving is also largely practiced in France, Belgium, and Germany.

The house of Heinr. Ad. Meyer, of Hamburg, is the most extensive dealer in ivory and its substitutes on the continent of Europe. Theirs is also the most extensive manufactory of piano-keys, billiard-balls, and knife-handles in the world.

CLASS 6.—FURNITURE.

16. The exhibit of articles in this class was probably more extensive than in any other in the exhibition; it was almost boundless in quantity and variety. The manufacture of furniture is very extensively pursued, both in Germany and Austria, and has been brought to great perfection in design as well as workmanship. The work in these countries is usually done by machinery, and they can, not only compete with other nations at home, but are enabled to export very largely.

One of the most notable, and to the American most interesting, kinds of furniture is that which is called bent-wood ware. It is to be met with all over Germany and Austria, principally in the form of chairs, lounges, and lighter furniture. It is remarkable for its neatness, clean finish, light lines, great strength, and its very few joints. This reduction in number of joints is accomplished mainly by bending the wood used, so as to require as few pieces as possible. An ordinary chair contains only six pieces besides the cane seat, and is an article which has no superior in its way. The construction of this furniture became an object of great interest to the writer, and he was, therefore, glad to accept an invitation to join an expedition, provided by the liberality of the vice-president of the grand jury, Mr. Joseph Thonet, to some of the factories of his firm—situated in Koritschau, Bistritz, Hallenkau, (all in Moravia,) and Great Ugrocz, (in Hungary)—which, together with their twenty auxiliary establishments, employ 5,200 work-people, male and female, and require motive power to the extent of 440 horse-power. Our visit extended to Great Ugrocz and Bistritz. At the former place, there are thirty thousand acres of mountain beech-forest. Beech is the only kind of wood used in the furniture in question, for which use it seemed to be excellently adapted. The trees being felled, the tops are removed and made into charcoal for use in the glass-works of Bohemia. The trunks are hauled to the mills, and sawed into planks of suitable thickness by gang-saws. The planks are in turn ripped up, with circular saws, into square pieces for turning. If intended for the back and hind legs of a common chair, which are composed of only one piece, the square piece of proper length is put into a kind of gauge-lathe, which does its work very rapidly, and varies the size where needed. The ordinary dowel-lathe is used for pieces of uniform size, such as the hoops, which are placed inside of the legs to stay them, instead of straight pieces or rungs. These hoops in the bent-wood chairs are so placed as to make it impossible to put the feet on them at any time. After being rounded as required, the wood is steamed in the green state for twenty-four hours in boilers adapted to the purpose. It is then taken out and bent to the shape desired, on a cast-iron frame, by hand. If intended for the seat, the piece is first strapped with iron on its outside, so that the bending shall be a process of compression lengthwise rather than an expansion. It is then attached

by one end to a pattern fastened to a turn-table, the other end being held by a chain wound upon a drum, to which is applied a brake so as to regulate the tension with which the piece is delivered to the pattern. The turn-table is then set in motion, and winds the wood upon its own form. If designed for a scroll, the pattern may be complicated and in several pieces, which are put in place at the proper time in the progress of the rotation. If for a double scroll, two of the tension-bands are employed. Much ingenuity is shown in devising these patterns and the mode of working them. The pattern is of cast iron, and the article bent to its shape is fastened to it, and so remains until the drying process has so far progressed that the wood will remain fixed in the shape thus given it. Steam-heat is used for drying. When thoroughly dry, the parts are forwarded to the filing or rasping shop, where they are clamped to a bench and filed all over with great care, and sand-papered. This work is largely done by females. The work is now ready to be stained and French-polished, each piece being done separately. This process, in my opinion, is the most important one in the Austrian bent-wood art, and no imitation will be a success without it. This work of staining and polishing is also done by females for the most part. The pieces are clamped to a bench, and each person has as many pieces in progress at a time as will dry, as she rapidly passes over them, in time for the next round. The process of polishing is one in which the sense of touch is an important element in the skill employed; and this can only be acquired by considerable experience.

The next thing is the setting up. This is done by having a frame which will hold the several parts in their proper places at the points of contact, and where a firm connection is to be made a saw of the proper thickness is passed between the pieces, making even surfaces for a joint. At such joints, glue is applied, and the parts are secured firmly with ordinary wood-screws or small bolts. The common chair is made to be taken apart for packing—the front legs and seat in one piece, the back in another, the hoops for legs, &c., the third. Three dozen of these chairs are packed in a medium-sized box; they are sent to all parts of the world.

The operations described are those used in producing only the simplest and commonest chair of this class of manufacture, and are given only to show the process of making, which can be extended to the most elaborately ornamented and complicated work of this kind.

To show how wonderfully this system of bending wood into shape can be utilized, it may be stated that the Thonets exhibited at Vienna a chair made from a single piece of wood 36 feet long, including seat as well as frame; the bending and combination into the shape required was a work of extreme ingenuity, and it was calculated most admirably to give an idea of the ductility of wood when properly treated. About fifty varieties of chairs are made by the firm in question, ranging in price from 3 to 25 florins, (a florin is equal to 50 cents of American

money;) thirteen kinds of sofas, from 14 to 38 florins; eight styles of tables, from 26 to 48 florins; piano-stools, foot-stools, &c., were also shown in great variety. They also exhibited quite a variety of fancy work, twisted pillars, and cornices, indicating the great range of application of this industrial process.

The common furniture of Austria is extremely monotonous in appearance; and, although neat and well made, the diagonally-veneered margins of the panels are uniformly surrounded with a kind of flute or thumb-molding, which makes it appear that the general style is subordinated to the finish. French polish is universally used for finishing, and it makes even the commonest work look very neat. In the better grades of furniture, however, much variety and invention is shown.

What seemed very commendable in the exhibition was that the upholsterer and furniture-manufacturer had been allowed to exhibit together. By this arrangement, room after room was shown completely furnished, the articles being all in harmony one with the other, and the general effect heightened by the arrangement of a thin screen of cotton spread over the top of the inclosure fitted as a room, to tone the light without dimming it materially.

Some of these inclosures, or rooms, were quite unique in their arrangement. In one of them, a smoking-room, the carpet, wall-paper, and curtains had the tobacco-leaf worked into the design. The renaissance style was prominent in the best work, showing how intimate are its relations to modern art.

It may here be remarked that the question of good taste in style and make-up was held paramount in deciding awards of premiums in this group. It was extremely difficult at first to decide in what good taste really consisted, after having so long heard the French styles and makes extolled as models of good taste. Now, however, we are inclined to think that this standard is not the correct one; it is too elaborate and ornate to satisfy American taste. Indeed, it may be said that the French exhaust art in their efforts after the new, the strange, the grotesque, and the beautiful. Some pieces of *salon* furniture exhibited by M. Chistofle, the great Parisian manufacturer of fine bronzes, were so heavily and elaborately covered with silver, gold, ivory, and bronze ornamentation as to afford a remarkable instance of the excesses referred to. The French fashions of furniture have long been regarded by the nations of Europe, excepting perhaps Great Britain, as the perfection of art. With Americans, the tendency is very much in the same direction, and good taste is sacrificed to circumstances connected with a certain branch of our industry. In other words, it would appear, that our styles of ornamentation in furniture are now adopted more with reference to the capacity and peculiarities of our universal wood-molding machines, than to real beauty and to the other attributes of good taste.

Before concluding this digression, it may be stated that the furniture of

all countries exhibited was generally made for actual use, and, with the exception of some Italian, French, and German work, could be seen in counterpart everywhere on the continent, at the houses of well-to-do citizens.

Vo. Fratelli Panciera-Besarel, of Venice, exhibited a French walnut mantelpiece, with a beautifully-carved representation, in relief, of a mythological subject. The Prince of Wales had ordered from this manufacturer some ornaments in wood-carving for his palace; these were exhibited, attracting much attention. They consisted of a pair of pedestals for candelabra or vases, each composed of five Cupids climbing one upon the other; the lower ones showed by their facial expression how heavy was the burden which they bore; the upper ones expressed similarly their satisfaction at being uppermost.

Cav. Gio. Bat. Gatti, of Rome, showed a splendid jewel-case of ebony, inlaid with ivory and different light-colored woods, with a little bronze statuette. It was of the old Byzantine style, and was reputed to have been sold in London for £1,200.

Gueret Brothers, of Paris, showed tasteful wood-carving, on a side-board cabinet. Henri Fourdinir, of Paris, exhibited a splendid set of drawing-room furniture in marquetry and wood-carving; also a fine set of ebony and ivory-inlaid tea-poys. This firm claims to hold a patent on a specialty of carved marquetry, but the fact that the Japanese have long practiced this art invalidates this claim. A cabinet of this style was sent in 1867 to London, and realized 75,000 francs. At the exhibition, they had two album-covers, magnificently carved and finished, one of which was sold to the Museum of Pesth for 1,500 francs.

Jackson & Graham, of London, exhibited the most elegant and best executed work in furniture in the entire exhibition. The furniture thus contributed consisted of cabinets, tables, jewel-cases, library and glass cases, and numerous other articles, all of which were worked in rose-wood, inlaid and marqueted with most, if not all, of the finest known woods. One of the articles shown was an ebony cabinet, 7 feet 1 inch wide by 7 feet 7½ inches high, which was inlaid with box, purple, orange, and gray maple, and holly woods; it was Italian in design, with Greek ornamentation. This article was worth £2,500. Another ebony cabinet, inlaid with ivory, and engraved and relieved with precious stones—lapis lazuli and jasper—and of Italian design, was sold for £5,000.

We may here state that while in London we visited the factory of Jackson & Graham, where we were courteously received and afforded every facility for studying the various processes of inlaying. The art of inlaying has been practiced for many years among the Italians, but it is only recently that it has been brought to comparative perfection. The inferiority of the old style of Italian work was due to the circumstance that the artisans of that country were in the habit of cutting the ornament and the ground wood together, thus leaving the work open, and thus they were never able to cut a sharp pattern on the leaves;

this marred the grace of the design. The work of inlaying is now done as follows: a drawing of the design is first made for the workman to copy after. This is either made on metal and printed, or lithographed in fine, clear, black lines—the finer the better. The veneers of the colors needed are then selected, and the various portions of the design are fixed on them, cut out, and fitted together. When the ornament is formed, the drawing of the work is taken, and a piece of thin tissue-paper spread over it and well secured at the corners to prevent slipping. Through this tissue-paper, the lines of the drawing are visible; the cut ornament is then taken piece by piece and fixed with gum on the tissue-paper, according to the colored drawing furnished with the outlines. Care is taken that the gum does not get on the edges of the pieces, as it would prevent perfect tracery when completed. A piece of paper is next covered on one side with lampblack mixed with turpentine, and left to dry. This blackened paper and a sheet of white are then placed between the drawing and the tissue-paper. A thin pointed instrument is used to mark around the ornament, the blackened paper yielding to the white a black line at the point of pressure, thus producing a correct copy of the ornament made. This impression is then fixed on the ground-veneer by compression; great care being taken not to stretch the paper or tear it. The ground-wood is then cut with great care to receive the ornament. By this means, the work can be done with great precision, and the workman is enabled to use woods in his design as light as those in the ground, without fear that the joint will be seen. The cutting is done with a very fine buhl-saw, the upper part of the frame of which is guided on a horizontal rod, the frame being operated in a horizontal position with the blade of the saw placed at right angles to it. The veneer is held in a vise operated by the foot, and made to move the wood to the angle or line cut instead of moving the saw to the line; the work requires a steady hand and much practice.

Jos. Hassa & Son, of Vienna, exhibited a remarkable black-walnut carved bedstead with canopy, in the style of Louis XIV. It was so completely covered with carvings, representing Cupids, flowers, fruits, and arabesques, that scarcely a piece of plain wood was visible, and yet, in spite of this, the general effect was very pleasing.

Bernhard Ludwig, of Vienna, exhibited dining-room furniture, with marquetry in rose, ebony, and maple. The chairs were upholstered with green embossed leather. He also exhibited bedroom furniture, with somewhat more elaborate ornamentation. Even in these elegant displays, the old Austrian fashion of diagonal margins for panels was seen to prevail.

Heinr. Dübell & Son, of Vienna, had a notable sideboard renaissance, in French walnut, with carved inlaid ebony marquetry.

Names, which have been mentioned in these cases, are those of exhibitors who gained the highest prizes.

A wardrobe of real ebony, from Danzig, was a masterpiece of joiners'

work. A pier-style cabinet from Copenhagen, paneled with foiled tortoise, giving it a dark-green and dark-red veined tortoise effect, was also a very fine piece of workmanship, and in good taste. From Germany, a jewel cabinet, and a set of dining-room furniture in renaissance, were very beautiful. Dresden contributed showy cabinets in renaissance style, and a section of dining-room wall with sideboard, panels, and doors, all in harmony, of the same style, and carved in French walnut.

Nicholas Strange, of St. Petersburg, Russia, showed a set of dining-room furniture of Russian style, carved in oak, which was really very fine. It was sold to the Archduke Charles Louis of Austria for 6,000 rubles, ($5,000.) The pavilion of the Emperor of Russia was furnished by this artist. That portion of it in the Emperor's sleeping-apartment was valued at $8,500.

Venice showed very good examples of Italian furniture, among them a round table, with inlaid and mosaic work representing five scenes in the life of Christopher Columbus. Rome and Milan exhibited jewel-cases, Pescia cabinets in free relief, and fine drawing-room furniture, but these were deficient in style and taste.

Paris contributed spring-beds in a French house, finely-carved dining-room furniture in antique styles, furniture of various styles, including an ebony carved chair, which was particularly worthy of notice, and a novel kind of folding-chair.

Johann Podstata, of Vienna, exhibited a great variety of childrens' beds and cribs. These Austrian cribs are peculiar, and have some points of merit. Their sides are quite high, and made of a network of stout cording, depending from a top railing running around and secured below. On one side, however, the railing is composed of an iron rod looped at each end into upright iron rods terminating at the top in a kind of sharp bend, over which the looped rod is carried when the side is to be closed. When it is desired to open the crib to put in or to take out the child, the rail, or looped rod, is lifted up and then pulled down; the network folding upon itself like a piece of cloth.

Among the noteworthy Vienna furniture were wardrobes by J. Mannstein, one of which, upon being unfolded, made a bedroom 8 by 10 feet, with 8 feet ceiling, and containing a bed, table, wash-stand, looking-glass, and seats.

The Tyrol showed some fine furniture finished in marquetry.

Pesth had some good furniture on exhibition, including sideboards, extension-tables, library-desk, table, and other things.

Judging from specimens exhibited, it would seem that Japanese lacquered ware of the better grade is very superior. It was distinguished from the other articles of its class by raised figures in gold upon a black surface. It is distinct from the Chinese makes in this and other respects, the latter never producing such good work.

While on the subject of Japan wares, it may be remarked that the

lacquer of the Japanese is so much superior to our best methods of polishing, that it seemed a duty to take special pains to learn as much as possible about it. Through the kindness of Dr. G. Wagener, an attaché of the Japanese commission, the attempt was partially successful. The Japanese exhibition was quite well represented in this lacquered ware, and it attracted much attention. It is well known that their wooden ware finished with this lacquer is not injured by hot water. Their cups in which tea is steeped are of wood, covered with lacquer. We are using gum copal to finish the best work on our pianos, which, when finished, are quite satisfactory in appearance, but are easily ruined by atmospheric and other influences. One firm in Boston has lost $8,000 a year by the failure of the very fragile surface given by this gum. The following is the process as given by Dr. Wagener:

"NOTE UPON THAT KIND OF JAPANESE LACQUER CALLED 'SHIUNKËI.'

"If the wood to be varnished be very porous, and the pores large enough to be visible to the naked eye, they are filled with a mixture of stone-powder and the lacquer called 'seshime,' which is merely the sap of the branches of the varnish-tree, without any mixture. This paste of stone-powder and lacquer is put on with a wooden spatula, the workman taking good care to press hard on the spatula, so as to fill up all the pores, and to rub the varnish off the surface of the wood, which is to be kept as clean as possible. After the varnish is well hardened, the whole surface is polished with a soft stone—a kind of wedge-stone—so that the veins of the wood come out again. This filling process can be repeated, if necessary. Next, in order to give it a color, the wood is painted over with a thin water-color, or it is stained. When thus prepared, the object is then varnished with the lacquer shiunkëi, of which a thin coating is put on with a brush; otherwise it would look too dark. On account of this lacquer taking its gloss in hardening, it requires a skillful person with a light hand to obtain a good result. Only one coating is given.

"In case the wood is close-grained and of even surface, the preliminary work will be unnecessary. The sheshine lacquer is alone used. It is rubbed into the wood with a ball of cotton, which is saturated with it. After it has been rubbed in, that which remains on the surface is taken off by rubbing with Japanese soft paper, so that in fact only a very thin layer remains.

"It sometimes happens that a Japanese lacquer is too thick, and will not spread evenly with a spatula, as occasionally happens when it is mixed with stone-powder. When this occurs, the Japanese workmen add to the varnish they are about to use powdered camphor. By this means it becomes more liquified and flows much better.

"There is another thing about the Japanese method of using this varnish that is worth knowing. The atmosphere in which it is to harden, after it has been applied, should be moist, and the room darkened. The

Japanese lacquerers have in their work-rooms large boxes fixed against the walls. These are furnished with sliding-doors. The inside of these boxes are wetted with towels dipped in water; the lacquered ware is introduced, and the doors are closed. It generally requires forty-eight hours to harden the lacquer."

Returning to the description of the goods exhibited. Persian mosaics were represented by a small table, which was covered with beautiful designs in eight or nine different colored woods.

The billiard-tables of Austria and Germany—the only countries exhibiting—were neat, and might answer well enough for amateurs; but skilled players would condemn them, and they would suffer by comparison with American and French tables. The principal manufacture of these tables has its seat in Vienna. Two firms, of Mayence, represented Germany.

The Austrian style of furniture held a third rank—not, however, because it was inferior to other makes, but from its monotonous uniformity in style; it all presented the same general features and similar patterns, and exhibited a persistent adherence to diagonals and margins of panel-work.

France, on the other hand, showed a talent for design and ornamentation in furniture which was marvelous and oppressive. But the French are continually overdoing the work which they can do so well. They hide the real merits of their designs beneath effects which are too rich and gorgeous.

The English show a kindred taste to ours in their furniture. It is generally well conceived in design and tasteful in ornamentation. Here, perhaps, may be most properly mentioned the exhibit of the firm of Battany, Heywood & Hancock, whose pavilion in the rotunda contained ebony and scarlet silk-upholstered drawing-room furniture, having a most novel and unique effect; they claimed it as original and of their own invention. It probably was; but it was too new and strange and odd for the jury to criticise, and it received no award. Whether its design was really meritorious or not would, we are convinced, be as difficult to decide as an abstruse question in metaphysics.

CLASS 7.—FANCY GOODS.

17. This class embraces all kinds of small notions—boxes, cigar-cases, watch-stands, and toys of wood and of other materials.

Switzerland has a regular and large trade in this line with all parts of the world, notwithstanding that they are produced principally by hand.

But Germany, more than any other nation, excels in this line of industry, having whole towns, cities, and communities almost entirely devoted to this business. The Black Forest toys are known all over the world; and from Baden, in that district, and from Nuremberg, in Bavaria, the entire continents of Europe and America are supplied

with cheap wooden toys and "knicknacks." Nuremberg also has a large trade in jewel-cases, glove-boxes, photograph-frames, and writing-desks; her trade is about $400,000 per annum. Thuringia, Saxony, and Würtemberg also have an extensive trade in wooden toys. Furth, in Germany, has also a considerable manufacture of fancy goods—making jewel-cases, glove-boxes, cigar-stands, writing-desks, &c.

Austria produces very largely of pipes and cigar-tubes, in box, brier, and cherry woods. An extensive business is also done in fancy boxes. Among the Austrian collection of fancy wares were shown specimens of handiwork, consisting of articles of household and ladies' use, carved in box, walnut, and rose wood, made under the patronage of the Society for Promoting Education located at Haindorf. There were also exhibited a collection of fancy articles carved in pine and black walnut, from the district school of wood carving at Werdenfels, Bavaria.

The articles contributed by the Chinese and Japanese showed great skill in execution, but were generally of too costly a nature to become articles of commerce. These eastern people seem to take a pride in imitating European or American inventions, which they reproduce in such perfection, and at such an expenditure of time and labor, that only the very wealthy can afford to pay prices that will remunerate them.

Paris—not France at large—has quite an extensive manufacture of goods of this class, but of the better grades, and is famous for good taste and artistic execution.

Class 8.—Machine-cut articles, etc.

18. In Austria, the forest districts in Hungary, Bohemia, Moravia, and Lower Austria are largely drawn upon for lumber to supply the demand for articles falling under this head.

One small forest in Galicia produces about 300,000 slats per month, worth $20 per thousand, and 100 bunches, of 500 sticks each, of match-wire.

Prince Schwarzenberg's domains in Steiermark yield 5,000 bales, of 100 bunches each; these bunches are composed of 500 pieces each, from 24 to 32 inches long. These domains also produce about 1,000,000 feet of moldings per year. There are also, throughout the empire, many factories of minor importance, which in the aggregate produce a large amount of this kind of work.

In Germany, the most important work in match-wire is carried on in Passau, Bavaria. The same firm, Hals, also produce excellent heels for ladies' shoes.

Sweden is also quite largely engaged in the production of this kind of goods, having some twenty-four factories engaged in it. In Jonkoping, one factory alone exports yearly a million dollars' worth of matches.

Class 9.—Willow-ware.

19. Willow-ware is a large industry in Europe, the principal places of manufacture being Munich, Herz, Anhalt, Lichtenfels, and Redwitz,

in Bavaria; Guben, in Prussia; Coburg, in Saxony; Vienna, in Austria and Brussels, in Belgium. S. A. Gosser & Co., of Redwitz, are said to have a very large business with the United States.

Sweden has, of late, commenced the cultivation of this industry.

There was nothing particularly new or striking in this class to deserve special note; the business being an old one, the styles to some extent fixed, and the range of its application, it would seem, nearly exhausted.

CLASS 10.—WOODS FOR MUSICAL INSTRUMENTS.

20. In Germany, the production of woods for sounding-boards and key-movements—for which a fine-grained slow-growth pine is necessary—is principally confined to Upper and Lower Bavaria.

In Sweden, the technical factory at Kulla produces a considerable number of sounding-boards.

The Austrian forests furnish wood very largely, not only for sounding-boards and key-movements, but for violin and viol bodies, guitars, mandolins, and zithers. Prince Schwarzenberg's forests in Bohemia produce annually 250 cases of sounding-boards, 8,000 bunches of key-movements, about 20,000 packages of covers for large basses, violins, violoncellos, mandolins, and guitars, besides 5,000 packages of wood for various other musical articles. Bezan and the state forest at Salzkammergest, Hinterberg, also produce a superior quality of sounding-board.

CONCLUSION.

21. In concluding this report, we may record the number of exhibitors in Group VIII, and the countries they represented. In the following list, they are arranged alphabetically:

	No. exhibitors.		No. exhibitors.
America,	12	Hawaii,	1
Austria,	448	Italy,	178
Belgium,	22	Japan, a large collection.	
Brazil,	7	Monaco, a small collection.	
British India,	21	Netherlands,	10
China,	9	Persia,	3
Denmark,	21	Portugal,	12
Egypt,	8	Roumania,	23
England,	26	Russia,	30
France,	32	Spain,	36
Germany,	274	Switzerland,	67
Greece,	5	Sweden,	24
Guatemala,	1	Turkey, three collections.	
Hungary,	125	Tunis, one collection.	

In conclusion, something should be said of the way in which the people of Vienna, and indeed of the whole Austrian dominions, came forward

with their wares and products to make the exhibition a success. The exhibition itself was a mammoth one, and more truly a "world's fair" than probably any other ever held in Europe. But its very magnitude showed that the amount of patient labor and attention to detail in getting it up must have been something quite enormous. But the committees, heartily seconded by the people, were untiring in their efforts, and there was probably no considerable manufacturer in Europe that did not have a special invitation to exhibit. The exhibition, too, was carried out in the face of an opposition, which endeavored to frighten people away from Vienna by rumors of high charges and of the prevalence of contagious diseases. Though not a financial success, it was a success in every other respect.

It is to be hoped that our people will accept a lesson in this respect from Austria, and, sinking all sectional littleness of feeling, unite in the work of hearty co-operation to make our Industrial Exhibition on the occasion of our first Centennial Celebration in 1876 an affair worthy of a people, enterprising, ingenious, and successful in the mechanic and all other arts.

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D.

WORKING OF STONE.

L. J. HINTON.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON THE

WORKING OF STONE;

AND ON

ARTIFICIAL STONES.

BY

LOUIS J. HINTON,
MEMBER OF THE ARTISAN COMMISSION OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

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CHAPTER I.

STONE-CUTTING MACHINES.

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1. TILGHMAN'S SAND-BLAST—In the American section of the Machinery Hall, there was but one piece of machinery that could be applied to stone-work—Tilghman's sand-blast. This, however, was so excellent a device, and so simple, that it attracted a large share of attention both from the general public and the practical men of all countries.

In a paper read at one of the meetings of the British Royal Institution, Professor Tyndall gives a very interesting account of the sand-blast. Speaking of that large statue, the Sphynx of Egypt, he says:

"It is nearly covered up by the sand of the desert. The neck of the Sphynx is partly cut across, not, as I am assured by Mr. Huxley, by ordinary weathering, but by the eroding action of the fine sand blown against it. In these cases nature furnishes us with hints which may be taken advantage of in art; and this action of sand has been recently turned to extraordinary account in the United States.

"When in Boston, I was taken by Mr. Josiah Quincy to see the action of the sand-blast. A kind of hopper, containing fine silicious sand, was connected with a reservoir of compressed air, the pressure being variable at pleasure. The hopper ended in a long slit, from which the sand was blown. A plate of glass was placed beneath the slit, and caused to pass slowly under it; it came out perfectly depolished, with a bright opalescent glimmer, such as could only be produced by the most careful grinding. Every little particle of sand urged against the glass, having all its energy concentrated on the point of impact, formed there a little pit, the depolished surface consisting of innumerable hollows of this description. But this was not all. By protecting certain portions of the surface, and exposing others, figures and tracery of any required form could be etched upon the glass.

"The figures of any open iron-work could thus be copied, while wire-gauze placed over the glass produced a reticulated pattern. But it required no such resisting substance as iron to shelter the glass. The patterns of the finest lace could be thus reproduced, the delicate filaments of the lace itself offering a sufficient protection. All these effects

have been obtained with a simple model of the sand-blast, devised for me by my assistant. A fraction of a minute suffices to etch upon glass a rich and beautiful lace-pattern. Any yielding substance may be employed to protect the glass. By immediately diffusing the shock of the particle, such substances practically destroy the local erosive power. The hand can bear without inconvenience a sand-shower which would pulverize glass. Etchings executed on glass with suitable kinds of ink are accurately worked out by the sand-blast. In fact, within certain limits, the harder the surface the greater is the concentration of the shock, and the more effectual is the erosion. It is not necessary that the sand should be the harder substance of the two; corundum, for example, is much harder than quartz; still, quartz-sand can not only depolish, but actually blow a hole through a plate of corundum. Nay, glass may be depolished by the impact of fine shot, the grains in this case bruising the glass before they have time to flatten and turn their energy into heat. * * * * * *

"But we can go far beyond the mere depolishing of glass; indeed, I have already said that quartz-sand can wear a hole through corundum. This leads me to express my acknowledgments to General Tilghman, who is the inventor of the sand-blast. To his spontaneous kindness I am indebted for some beautiful illustrations of his process. In one thick plate of glass a figure has been worked out to a depth of three-eighths of an inch. A second plate, seven-eighths of an inch thick, is entirely perforated. Through a circular plate of marble nearly half an inch thick, open-work of the most intricate and elaborate description has been executed. It would probably take many days to perform this work by any ordinary process; with the sand-blast it was accomplished in an hour. So much for the strength of the blast. Its delicacy is illustrated by a beautiful example of line-engraving, etched on by means of the blast."

The reputation of Professor Tyndall gives weight to this testimony. No higher indorsement of the value of Tilghman's invention could be obtained in Europe, even should it be desired.

2. The inventor says of his sand-blast that it can be applied to glass, stone, wood, or metal. The efficacy of the blast depends upon its force. The sand may be either propelled by steam, water, or air; but steam is generally to be preferred where high velocities are required.

When a large quantity of material is to be removed, as in the ornamenting of stone, a steam-jet of from 60 to 80 pounds pressure is used. In this case, the stencil is made of iron or rubber; but when a small quantity of material is to be worn away, or the surface is merely to be depolished, as in ornamenting glass, a jet of air, from one-tenth of a pound to one pound pressure is preferred. With a low pressure, soft and delicate substances, such as paper-designs, lace, and leaves, cemented on glass, may be used. With a steam-jet, using steam sufficient for two horse-power, at 70 pounds pressure, and one pint of sand, 2 cubic inches

of granite, 4 cubic inches of marble, or 10 cubic inches of sandstone may be cut away per minute. It will be obvious that flat or curved surfaces may be alike acted on by this process, the blast being in all cases directed at right angles to the exposed surface. Besides executing ornaments in relief or intaglio, the process can be used for cutting grooves in quarries and in tunnels, for stone-dressing, or for cutting stone in lathes.

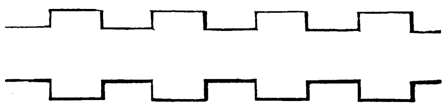
Mr. Tilghman, among other specimens of work executed by his sand-blast, showed at the exhibition a thin slab of Vermont marble perforated in the most beautiful way. It probably could not be executed at all by hand. Some letters were shown, cut into a lithographic stone in ten minutes. The shortest time in which an expert stone-cutter could execute the same work would be at least ten hours.

General Tilghman's invention stood without a rival, and it will probably soon be imitated and used in Europe, where its value is already acknowledged by all who have seen it.

3. HOLMES AND PAYTON'S STONE-DRESSING MACHINE.—This machine was exhibited in the British section, as constructed by the Patent Machine Stone-Dressing Company, 21 Great George street, London. Although appearing in the British section, its inventor is an American.

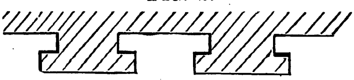
It consists of a massive cast-iron frame, with two vertical standards, one on each side of the bed-plates. Upon the cast-iron bed-block is placed a strong, sliding bed-plate, upon which the stones to be dressed are secured. The upper surface of this bed-plate is divided into a number of grooves, parallel to each other, but formed with recesses at short intervals, as shown in the accompanying sketch, Fig. 1.

FIG. 1.



These broader portions are necessary, in order to lift out the dogs by which the brackets fastening the stone upon the bed-plates are secured. In section the grooves of the bed-plates are as shown in the next sketch, Fig. 2, and the dogs are of a form to correspond, so that they are held down by the recesses under the T-shaped projection. The length of the dogs is rather less than that of each of the broader portions of the grooves, so that by slipping the former back they are easily lifted out of place.

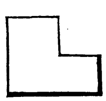
FIG. 2.



4. The tops of the two vertical side-frames are connected by a cross-head or tie-beam, and vertical openings are left in them for the whole length, to form the guide in which the blocks carrying the cutting-mechanism slide. In the upper part of these blocks is mounted a shaft, passing over the bed-plate of the machine, and about 6 feet above it when the blocks are in their highest position. The shaft has keyed upon it outside the frame a large pulley, driven from the motor by a horizontal strap. On the other end, also outside the frame, is a short

crank and connecting-rod, the normal angle of which is about 45°. Below this crank-shaft is another, also running in the same sliding-block, and carrying the cutters. One end of this shaft projects beyond the outside of the frame, on the same side as the connecting-rod upon the upper shaft, and has placed loosely upon it a large disk, about 2 feet 3 inches in diameter. Near the periphery of the disk are drilled fourteen holes equidistant from each other, and some 2 inches in dia meter. Projecting from one side of the periphery of the disk is a quadrant cast upon it, and with an outside attachment for the end of the connecting-rod attached to the upper shaft. It will be seen at once that when the upper shaft is caused to revolve, the connecting-rod imparts a reciprocating motion to the loose disk, but, of course, without affecting the cutter-shaft. On each side of the loose disk, however, and in rubbing-contact with it, are two similar disks, which are keyed upon the cutter-shaft. In the outer of these disks are drilled fifteen holes near the periphery, and exactly corresponding to those in the loose disk, excepting that they exceed the latter in number by one. When the fast disks are turned in such a position that one of the holes in the surface corresponds with one of those in the loose disk, a pin is used to couple both together, and then the motion of the connecting-rod at once imparts a reciprocating action to the cutter-shaft. Handles are fastened to the outer or fast disk, for convenience in turning it and and the cutter-shaft, to bring one or other of the cutting-faces upon the stone. It will be seen that by the simple expedient of having one less hole in the loose than in the fast disk, a very fine gradation of angle for the cutter can be obtained; in fact, the utmost range that is necessary is that within the limits of the quadrant cast on the loose disk, and to which two studs are attached, which, however, are free to slide in a curved slot cut upon the quadrant. The object of these studs will be seen presently. The cutter-block mounted on the lower shaft consists of a heavy piece of cast iron, with suitable recesses for holding the cutter. These are of two kinds: one pair on one side of the block, and extending for its whole length are steel teeth, with spaces between them, and of the form shown in Fig. 3. The width of the space is equal to that of the teeth. A row of these cutters is placed in the recess in the cutter-block, and keyed in at the end. The corresponding row in the other recess are arranged so that a tooth occurs in one row opposite a space in the other. The rows are placed each at an angle converging toward each other. On the opposite side of the cutter-block are placed, in suitable recesses, plain steel blades, with sharpened edges, merely kept in place by paper packing. These blades also converge toward one another. It will now be seen that when it is necessary to cut the stone with the teeth, if the steel blades are in contact with the stone, a half-turn must be given to the cutter-block, which is done by means of the handles on the fast disk, and, as the normal position of one of the two

Fig. 3.



handles always lies between the studs on the quadrant, it follows that when the cutter-block is thrown over, the opposite handle then falls between the studs. Again, if one set of cutters, either teeth or blades, is in contact with the stone, the handle comes home upon the lower stud, whereas, when the other row of cutters is brought into contact, the handle is thrown against the upper stud. Between these two extremes, any desired inclination is imparted to the cutting-tool by means of the holes in the disk.

5. We now come to the feed-motion of the machine. This is of three kinds: first, the rising and falling motion, given to the sliding-blocks in the frame, as the cutter follows up the stone in dressing it; second, the backward and forward motion of the bed; and, third, a hand-motion, for producing a fine cut, or relieving the pressure of the tool upon the stone.

To produce the first of these motions a vertical screw passes through each sliding block, and, by turning them in either direction, a rising and falling motion is obtained. They extend for the whole length of the guides in the frames, and pass below the bed-plate of the machine, where each terminates in a strong worm, gearing into a worm-wheel. This wheel is driven either to the right or left by bevel-gearing, a lever being under the hand of the operator. to reverse the action at will.

Similarly the strong pinion, driving the broad rack upon the under side of the bed-plate, is driven by bevel-gearing from the motor-shaft, and is also reversed at will by a clutch and lever. The hand-motion is merely a wheel gearing into the worms of the vertical screw-shaft. It is only needed to relieve the machine when taking a finer cut.

6. The action of the machine is as follows: When the cutter-block is set in motion by the oscillation of the disk, the stones gradually feed along on the bed-plates, and one row of teeth takes a biting cut, leaving a series of ridges, corresponding to the space between the teeth. The motion is then reversed, and the cutter turned over far enough to bring the other series of teeth to act upon the stone. These of course attack the ridges, and reduce the surface of the block to a level.

The cutter-block may then be thrown half over, so as to bring the knife-blades in contact with the stone. The action of these, which take a much more delicate cut, leaves a smooth, true surface, with scarcely perceptible ridges. The teeth leave longitudinal dressing-marks upon the stone, and the blades transverse marks. The angle given to the tool varies with the nature of the work, being greater for hard and less for soft stone.

The machine in the Vienna Exhibition would take a block 2 feet 4 inches high, and 7 feet long, and surfaced granite at the rate of about 2 feet a minute. The power required to drive it on such work was said to be two-horse power.

The writer is not able to state from his own knowledge whether similar machines are in use with us, but he has seen marks on machine-manufactured stone-work, wrought by the Bigelow Bluestone Company,

near Rondout, N. Y., and at Chicago, such as are left by the Holmes & Payton machine.

7. SIGNOR GUISEPPI ANNANI'S STONE-DRESSER.—The only other stone-dressing machine which we could discover among all the machines on exhibition in the vast machinery-hall adjacent to the exposition building, was that of Guiseppi Annani, of Verona, Italy. Little can be said of it, and that scarcely favorable. It was a clumsy, ill-made wooden frame, with a bed for the stone high above the ground. The feed was automatic, or would be if it could work, and consisted of a rack and pinion, driven through a ratchet and gear from a pulley belted from the motor. The so-called stone-dressing arrangement was formed of a set of six hammers, hung from a shaft; beneath them was a second shaft with six cams mounted upon it. The cams revolve, lifting the hammers consecutively, and then dropping them suddenly, each upon one of a row of chisels fixed in an inclined frame, and working loose in guides, with their cutting-edges resting on the surface of the stone. Spring-stops are placed above the hammers to prevent their rising too high when lifted by the cams. This idea is very old, and even if the present machine were perfectly made, it could never work with the slightest regularity or economy. Each chisel, operating on its own account, would penetrate more or less, according to the varying density of the stone; and this irregularity once having commenced, it would never be corrected. The machine of Signor Annani may be regarded as somewhat of a curiosity.

8. POWIS, JAMES & CO.'S STONE-DRESSING MACHINERY.—Near Holmes & Payton's machine, Messrs. Powis, James & Co., of London, exhibited a large stock of wood cutting and molding machines. Attention was attracted to their exhibit by two large pieces of stone molded into cornice lengths. Upon making inquiries, it was ascertained that this firm manufacture stone-cutting machinery, in addition to their other work. They did not exhibit it, but merely showed the two pieces of dressed stone just mentioned, to attract attention to the scope of the work done by their firm.

The address of a company in London was given, with the assurance that visitors to their works would "see some of the best stone-dressing machinery ever invented." Accordingly, on the way home, a point was made of finding them.

9. THE MACHINE STONE-DRESSING WORKS.—These works are located at York Road Station, Battersea Park, London. The firm is a "limited liability" company, which has purchased the patented invention of Mr G. Hunter and Sir William Fothergill Cooke.

The writer found a friend employed at the company's works, as fore man of the forty or fifty stone-cutters employed there, who kindly introduced him to Mr. G. Hunter, the principal inventor. This gentleman could spare very little time to give the details of construction of his machines, but gave references to different journals that had printed, at

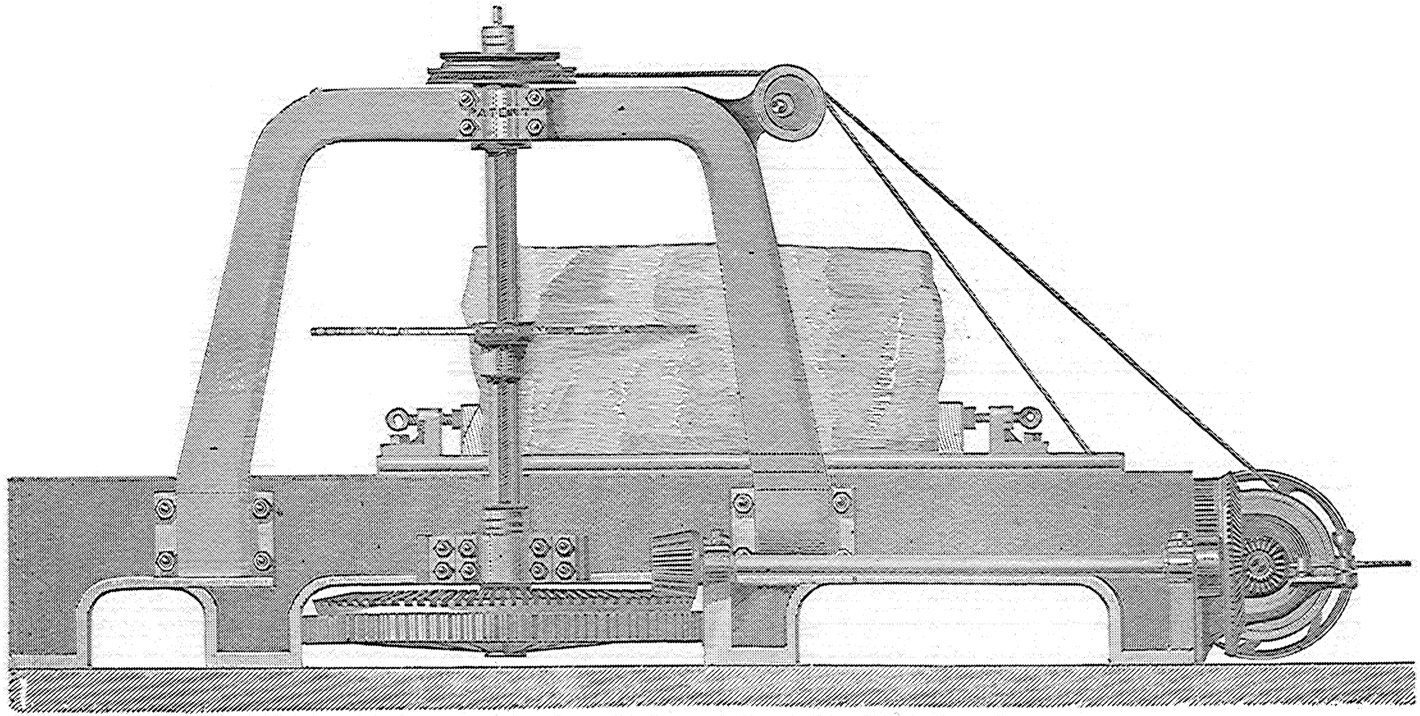


FIG. 4.—Hunter & Fothergill's stone-sawing machine, with horizontal saws—side view.

various times, more or less full accounts of his and his copatentee's invention. In a letter from him, written at the request of the writer, a brief history is given of the introduction of stone-dressing machinery in Great Britain, so far as his knowledge extends.

10. This account is as follows:

HISTORY OF STONE-DRESSING BY MACHINERY IN GREAT BRITAIN.—"I may say that 1832 was the year the first machine was made, but the Forfarshire machines were patented in 1834. To the best of my knowledge, these machines are chiefly used for dressing flags. Six of these were erected at Legsmill quarries, Forfarshire, Scotland. They were only partially successful, owing to the opposition of the journeyman stone-cutters. I may say that these six machines dressed all the planed flags shipped from Arbroath, up to the year 1846, when the proprietors erected two at the quarries belonging to Lord Panmure, but they only 'saked' the stone per superficial foot, which at this time was equal to £3 6*s.* 8*d.* per thousand superficial feet. The contract was generally let for £2 2*s.* 0*d.* This upheld coals and steel, and executed the work, taking an inch or an inch and a half off. In 1852, three more machines were erected for different parties. Since then, the gradual development of these machines took place, and now, I believe, there are nearly one hundred in Forfarshire; and while the export of machine-dressed flagging from 1836 to 1840 remained about 200,000 feet per annum, it is now about 2,000,000.

"In the year 1837, the railway block boring and facing machine was brought out and patented, by the same inventor, James Hunter, (my father,) of Legsmill, Forfarshire; but owing to the sudden disuse of stone blocks, this machine, although a success, became of comparatively little use.

"In the year 1852, I went to the Forest of Dean, to erect the Forfarshire machinery there, and having heavy, rough stuff to deal with, I went back to Forfarshire, and brought out a saw with tubular trumpet-mouth tools. This was of cast iron, and was 11 feet diameter. Another was made of 6 feet diameter. These machines were put to work in 1855, and are still at work. They cut the sandstone at 5 inches forward per minute," [the stone from the Forest of Dean quarries is stiff and hard, but of a fine grit,] "and the man attending used to have one penny per foot, superficial, for his labor, and sharpening tools.

"In the year 1862, I brought out the saws for cutting hard Welsh slate. These mounted several saws on a spindle above the table, and cross-cut a large slab into several pieces, the speed of cross-cutting being 4 inches per minute, through a depth of 12 inches. The tool in this case was of the solid trumpet-shape mentioned.

"I have also erected these saws 12 feet diameter, for squaring magnesian limestone blocks, for the Lyne pier commissioners. A fast-cutting machine was also brought out for cutting out slate-work from the bed. This machine cut into the rock two-thirds of its diameter, and

would cut 2 feet at a speed of from 4 to 5 feet per hour. A tunneling-machine was next patented. It cut a chase or groove around the rock, 2 inches wide and about 3 feet deep, doing the work, as a rule, in about three hours. We walled many yards with this machine. The price, as shown by the time-keeper's book, came to about £2 2*s.* per yard, for a 7 feet 4 inches tunnel. The rate, through solid slate, was from 9 to 10 yards, night and day. The solid core was removed at times, without

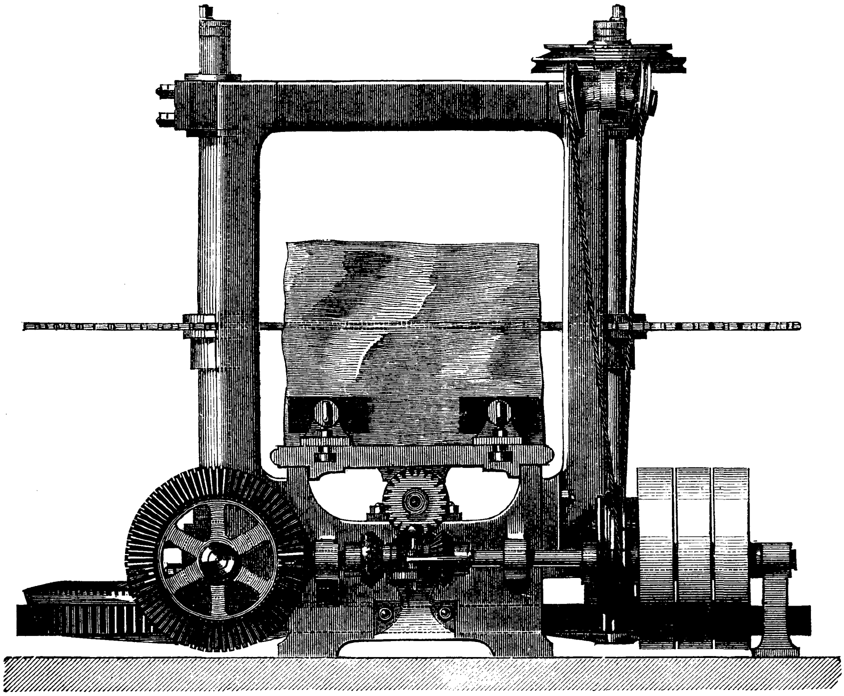


FIG. 5.—Hunter and Fothergill's stone-sawing machine—end view.

breaking it. The tunneling-machine weighs about ten tons. It has a revolving ring in front, in which pieces of steel securing the tools are fixed. It revolves at a speed of about 20 feet per minute for slate. It moves forward when at full speed at about three-eighths of an inch per revolution, and when working in pure slate makes several cuts without deranging the tools; but as spar very often occurs in slate, we, as a rule, had to change tools generally two or three times, for a cut of 2 feet 9 inches.

"The power required to drive the machine was double-cylinder, high pressure, four and a half cylinder, at about 35 pounds per square inch steam. This machine was invented for the purpose of proving slate-veins, and as it relieves a block, full diameter of the tunnel, slates or slabs can be made from it, to prove the general outturn of the rock.

"The next machine brought out by me was the molding-machine, as worked at York Road, Battersea, the chief feature of which is the em-

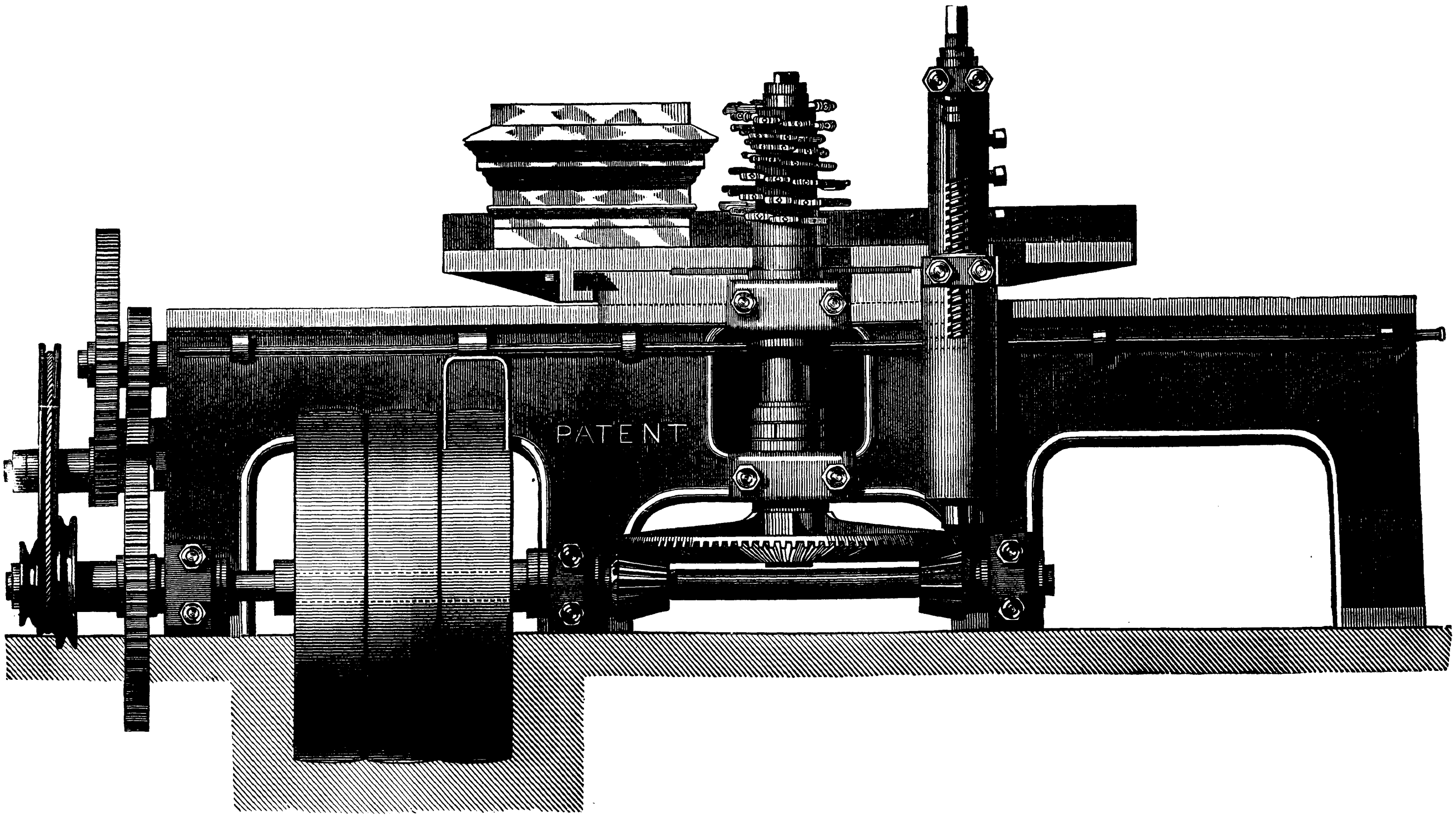


FIG. 6.—Hunter & Fothergill's stone-molding machine—front view.

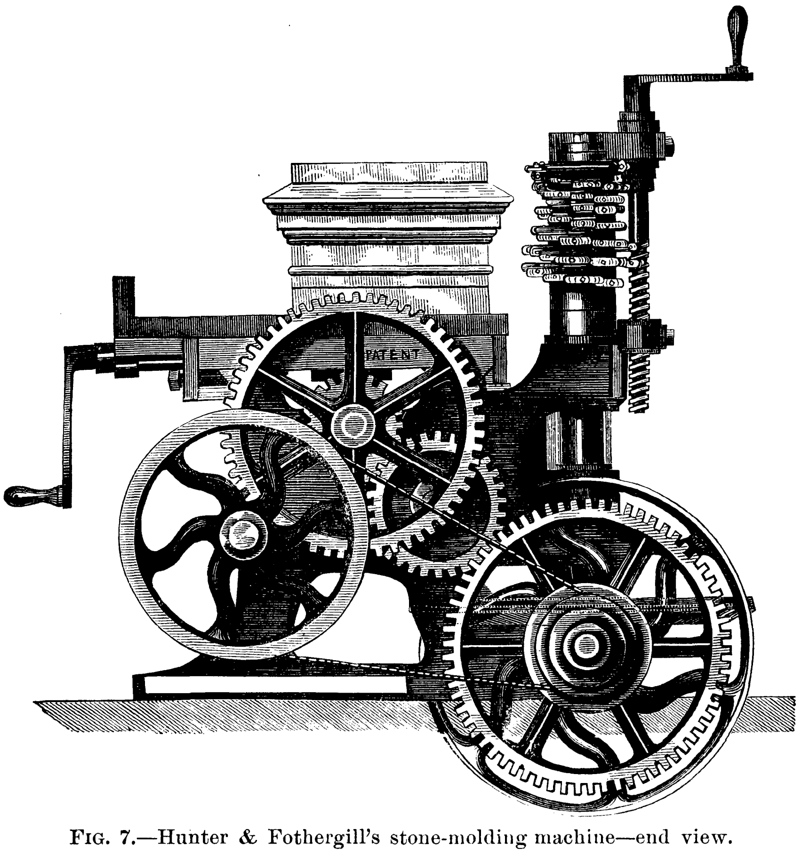
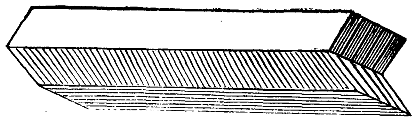


FIG. 7.—Hunter & Fothergill's stone-molding machine—end view.

ployment of plates of different lengths, all lettered, so as to be easily picked out and set, like types, to mold. These being built on a shaft, revolve, and take out the rough or waste, comparatively near the mold, when a tool to profile passes several times over and finishes the work. The stone is laid on a cant-table to cant to the proper angle.

"I also invented what is known in Scotland as Hunter's patent ridge stone-cutting machine, which cuts ridge rocks, one out of the other, at about 100 to 140 feet per day, according to the nature of the stone, as shown in Fig. 8. These ridges can be cut out even as thin as five-eighths of an inch. However, as there is such a great difference in stone, it is extremely difficult to know how to construct a machine that shall be applicable to all."

Fig. 8.



11. We were not able to see and examine the machinery at rest, but were permitted to see it in full operation. The following description* was carefully compared with the machine while inspecting the company's works, and was found accurate:

"Of the process of working, both in sawing blocks and rough-hewing moldings, it may be said *in limine* that one form of cutter is used, a steel face of five-eighths inch diameter, the metal tapering away from the face to give it a cutting-edge. For the saws, the teeth or cutters are cylindrical, tapering bolts, with flat heads, which do the cutting. The most powerful machine on the premises is an arrangement of a pair of saws, each 5 feet 4 inches in diameter, that work horizontally

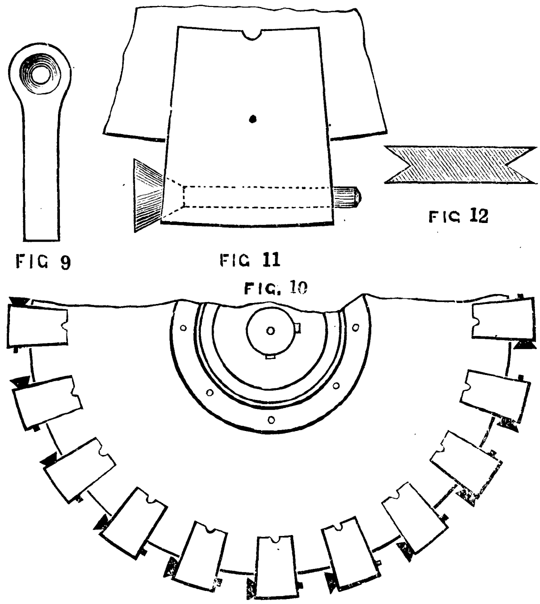


FIG 9 FIG 11 FIG 12 FIG. 10

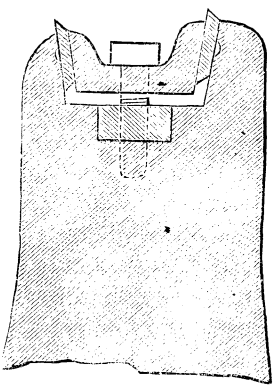
* London Engineer

upon upright shafts, and in work meet each other within about an inch. The sawn slab separates readily and uniformly at the middle of the piece left uncut. Each of these saws has forty-four cutting-tools round its periphery. These are carried by holders that are wedged into the outer edge of the saw-plates, and have holes forged in them for the reception of the tools, as in Figs. 9, 10, and 11. Fig. 12 shows the form of the edge by which the tool-holder is kept flush with the blade of the saw. A block of Portland stone, 5 feet 9 inches by 4 feet wide, had a slab of 2½ inches thick taken off by the machine in rather less than twenty-five minutes in our presence.

"The ripping-machine has tools of the same character as the slabber. The saws that work vertically are 2 feet 6 inches in diameter, and have each eighteen cutters. It is equal to taking three saws and cuts of about 8½ inches deep.

"Of the remaining machines, one operates by cutters arranged upon a vertical shaft; the others are fixed on horizontal shafts, that are raised and lowered, according to their work, with the greatest facility and nicety. The tools in these machines are of the same diameter as the saw-teeth—five-eighths inch—but are of punched disks of steel, about one-eighth inch thick. The form of their cutting-edge and the mode of fastening will be understood from the subjoined sketch, Fig. 13.

FIG. 13.



"The tools in the planing and molding machines are fastened to holders (Fig. 5) that are bolted to the shafts. There is a pair of tools at each end of the holder. Although the holders, when fixed upon the shafts, act obliquely, as appears upon the stone passing under the cutters, and in such manner as seems incompatible with the production of any definite form, they are nevertheless so arranged, and so act, as to turn out moldings of a large size, with many members, rough-cut with great accuracy. The work is finished by being passed two or three times under cutting or scraping tools of the precise form of the molding to be produced. For a molding of many members, some of them deeply cut, more than one of these finishing-tools is sometimes employed. The moldings, as completed, are equal to the best hand-work ever produced. Mitred work is also executed by the machines with perfect accuracy, as we saw from the return-moldings on the ends of the stair-steps in process of being dressed."

12. The stone mentioned in the above quotation, *i. e.*, Portland, is that quarried from the island of Portland. It is a limestone. In former years a much harder and more durable material was obtained than is quarried at present. The specimens which the machines were operating upon on the occasion of our visit were very soft and white, little

likely to stand the wearing effect of the weather. The great majority of the public buildings of London are built of this stone. The machinery of this company is peculiarly adapted to its manipulation, and for working of the many oolites found in England. We would also venture to use it on sandstone, not harder than Ohio sandstone. We have a large number of soft sandstones in our Western States, and in some of our Southern States, that this molding-machine would work well.

13. The sawing-machines are not, apparently, so well adapted to our needs as those already patented by some of our own citizens.

As a general rule, European manufacturers build more solidly than is customary with us. When we use sandstone or marble, in consequence of its great cost as a raw material, and the expense of working, we usually veneer our fronts with thin slabs, backing them up with bricks, and anchoring the stone to the walls. We make our material go further than any other people in the world. This veneering process is, of course, not always followed, as, for example, in the beautiful and solid buildings now erected or being erected under the superintendence of the Architect of the Treasury, Mr. A. B. Mullett. Buildings erected in our cities of granite or limestone are generally quite solidly built.

The point to be observed is this: the English sawing-machine, in making a cut, does not make a clean one or a narrow cleft. Indeed, by the time the faces have been on the rubbing-bed to be smoothed down, an inch of material has been wasted away. This would never answer with us where the kind of stone which this saw operates upon is so expensive.

14. YOUNGS' DIAMOND SAW.—Messrs. Young, of New York, have invented and patented a vastly superior saw. It is called "Youngs' reciprocating saw-machine for sawing stone." When exhibited at the fair of the American Institute last autumn, it attracted a great deal of attention, besides gaining the great Medal of Honor, which is only given to such inventions as are deemed of such importance as to be likely to work a revolution in industries to which they are applied.

The main feature of Young's patent is that of cutting the stone by means of diamonds, securely fastened into the saw-blades. They are held in steel cutter-blocks, and are fastened in by calking the steel, any little interstices that remain being filled with small pieces of iron and spelter solder. The art of setting them is so simple that any one can do it with ease, after once having seen it done. There is no necessity to describe it in greater detail. Suffice it to say that this machine seems superior to anything hitherto designed to perform the same work. On the score of economy it surpasses the machine at London, as it makes but a very narrow cleft, and leaves the face of the stone so smooth that little or no polishing is needed after it comes from the saw-bed. The diamonds are very seldom lost, and do not wear out. They are of an inexpensive kind, adapted to such work. Steel saws require a great deal of sharpening and replacing. Diamond saws will do more than

three times as much work with the same power as the old sand and iron saws, and the work is done from ten to thirty times as rapidly.

15. THE DIAMOND-SAW QUARRYING-MACHINE.—Willard, Whittier &

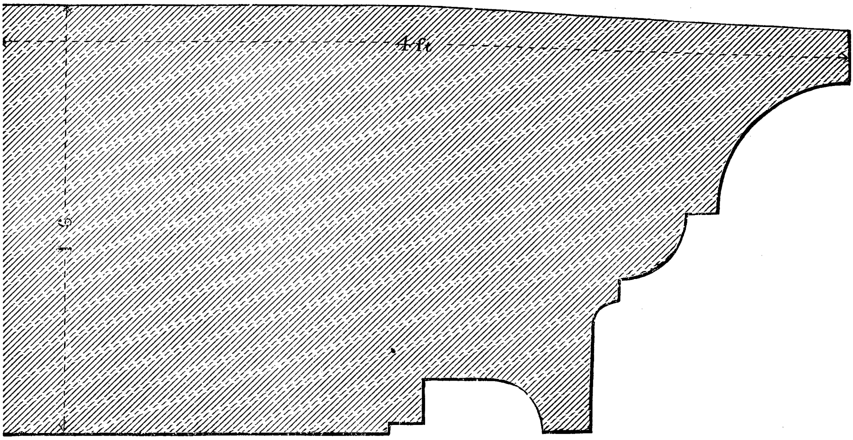


FIG. 14.—Cornice for new London post-office, (one-eighth full size.)

Co., of Boston, are the proprietors of a diamond-saw quarrying-machine, adapted to all kinds of rock-channeling and dressing, which surpasses the Hunter & Fothergill-Cooke machine, extensively used in

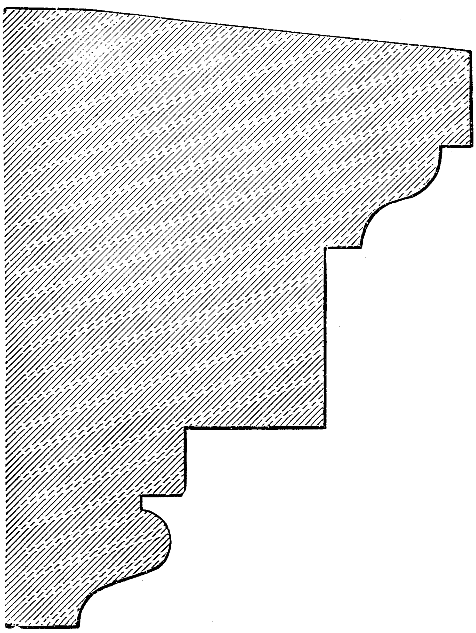


FIG. 15.—String course, new St. Thomas Hospital, (one-half full size.)

Great Britain, and already described. The Willard & Co. machine consists of a straight saw, armed with black-diamond cutting-points,

which vibrates between and works in combination with revolving diamond-pointed drills for the purpose of freeing the ends of the saw-kerf when operated in a quarry.

The whole is carried on a frame with a six horse-power engine and boiler, mounted upon trucks and placed upon a track to facilitate change of its position. It cuts a channel 11 feet in length, one-half inch in width, and 4 feet 10 inches in depth; it can be handled and worked by two men, is simple in its construction, and is easily kept in order. It is said to effect a saving of 50 per cent. over the cost of hand-labor.

16. Although not so successful with their saws, the English molding-machines are very clever inventions, doing their work better than anything the writer has ever seen or heard of, and they would doubtless prove of value if introduced on this side of the Atlantic. They are not likely to reduce the demand for stone-cutter's labor any more than the introduction of wood-molding machines diminished the demand for the labor of carpenters and joiners; still some opposition may be expected from the least intelligent workmen. A continuous stretch for a considerable length of one kind of molding would pay well, as, for instance, in the example shown in Figs. 14 and 15.

In concluding this portion of this report, it is well to call attention to the fact that it is only here and in England that any strong efforts have been made to master the art of manipulating stone by machinery, as we work wood and those materials which are even harder than almost any kind of stone—steel and iron.

CHAPTER II.

CUT AND CARVED STONE-WORK.

EXTENT AND CHARACTER OF EXHIBITS; WASSERBURGER'S MAUSOLEUM; METHODS OF BUSINESS; WORKING STONE IN AMERICA; WORKING STONE IN VIENNA; CONDITION OF VIENNESE WORKMEN; EDUCATION; METHODS OF DOING FINE WORK; USE OF STONE AND STUCCO; STAIR-WAYS.

17. There were not many specimens of this industry shown at the exposition, either within the building or on the grounds; certainly not nearly as many as were shown at former European world's fairs.

There was, however, an immense number of specimens of different kinds of stone and marble on exhibition. In some sections small blocks about 6 inches square were shown. Italy made a splendid display. Over a thousand different kinds were counted, all grouped with taste and harmonizing in color. Each kind is used by the Italians in some one or other of their many industries.

The exhibit in the United States section was but a small collection of pieces of about the right size. It was unfortunate that, after deciding to send the products of our quarries, the collection was not made more complete. A full exhibit of the immense variety of the fine marbles, granites, and other building-stones of the United States would not only astonish the people of Europe, but many of our own architects, who scarcely dream of the immense variety from which they might choose, if transportation were cheaper than it now is.

Some exhibitors made the mistake of sending huge blocks of rough-hewed marble, stone, and granite, which were brought hundreds of miles, to be dumped off the cars, and left where they fell, behind the exhibition building, no word of explanation being given. Small blocks would have done quite as well for exhibition, while the fact that large blocks could be quarried to order might have been stated in a printed form, if it was of sufficient importance to do so. The members of the jury, when viewing these solid blocks, walked around them, felt them, tapped them with their pencils, inquired where this or that specimen came from, and passed on to something that had work in it. As already remarked, there was not a very great amount of the latter kind of work exhibited, except, of course, marble statuary, of which there was a splendid show; Italy alone sending so much, and that of such a quality, as to make its remembrance pleasant to all lovers of the fine arts.

18. With the exception of one or two pedestals of granite, not worth noticing, the only good piece of stone-work to be seen on the grounds was a mausoleum, erected near the jury pavilion, and exhibited by Paul

Wasserburger, "surveyor of buildings, architect to the community, and stone-cutter to the court." The style of the mausoleum was Gothic; the design was by Frederick Schmidt, the detail drawings being furnished by his pupil, Charles Schoden. The sculptured figures at each corner, representing the cardinal virtues, came from the studio of the sculptor Louis Le Grain; the carving was executed by another academician, J. Pokorny. The following kinds of stone and granite were used in its construction: for the steps, grayish-blue granite; the columns, red Saxon granite; the body of the edifice was of a light-yellow freestone quarried on the estates of Count Auersperg and Baron v. Gagern, Mokritz, in Lower Carniola.

The design was very neat and chaste, but it contained nothing original. It was simply a reproduction of the ideas of the old Gothic architects, with some variation of the details. The manipulation was perfect. In this particular modern workers in stone can equal, if not surpass, the workmen of earlier times; and when this is written, all is written.

19. It may be well to note the fact that in Europe this business of stone-cutting seems to be in the hands of wealthy men, like Paul Wasserburger, whose business was founded by an ancestor in 1734, and handed down from father to son until it came into the hands of the present possessor. Small employers seem to be almost unknown in the large cities. Not so with us; we have many such, struggling to rise. Foremanships are the greatest prizes offered the best journeymen in Europe.

20. Within the palace, under the dome, was another specimen of the same class of work designed by the same architect—a stone pulpit and stair-case. The decorative part was executed by the royal sculptor, Franz Schöntholer. The stone used was also from the quarries of Count Auersperg and Baron v. Gagern. It was very fine, but there was nothing in it that the decorative stone-cutters in any of our large cities would not duplicate, if called upon to do so, without having "royal" or "sculptor to the court" attached to their names.

France displayed several marble mantels, and a fountain, all exhibited by Parisian firms. The fountain was nicely gotten up; dark-red marble built into the wall; above the water-bowl was a sculptured panel in white marble, which was executed in Italy, and represented an eagle swooping down upon a duck, surrounded with reeds and water-plants.

Fountains abound in the streets of Europe, a feature worthy of our consideration. Many are very beautiful, some are quaint, and all are useful and ornamental. Nothing is a more common sight to the traveler, nor does anything that he sees live so long in his memory as the public fountains in open plazas and market-places; time—evening, when the day-sky is changing into that of the night, the crimson flush in the west dying away into blue, and the stars just beginning to appear.

The cool splash of the fountain sounds pleasantly on the ear. Around it stand, picturesquely grouped, the girls and women who have come to fill their water-jars and to gossip with their neighbors. The gabled and many-storied houses around cast their shadows over them, making the background of a scene which, once seen, is rarely forgotten.

In London, there is a "drinking-fountain association"—everything is done in England by an association of some kind—which has procured the erection of three hundred and sixty drinking-fountains, besides many troughs for horses, cattle, and dogs. These fountains are nearly all of finely cut and polished marble or granite, or of elaborately carved and cut sandstone. Upon each is engraved the name of the donor, generally some wealthy citizen.

This association has performed an excellent temperance work. Before those fountains were erected it was extremely difficult to get a drink of water outside one's own home, while beer and gin shops were open on every side. With a few exceptions, this is the case in our own cities. Some of our many rich philanthropists, by erecting fountains like that at Cincinnati, works beautiful as well as useful, may be sure of winning the grateful thanks of thousands who would be thus benefited.

21. This kind of work in stone would be well adapted to exercise the skill and ability of the school of fine-art workmen which the last decade has raised within our midst. Some of the artisans, who are now American citizens, have cut and carved some of the best work in Europe. Indeed, we have workmen capable of executing the most elaborate and delicate work in stone, if the public will but give them a chance, instead of sending to Europe for anything of this character which they may want, and which many deem the American stone-cutter incapable of executing. But it is a fact that no better workmen can be found than our own. They work much faster than workmen in any other country. Indeed, they must of necessity do so. It is quite the exception to see workmen in Europe exert themselves. It is their quiet, careful working that produces the finely-finished work seen in Europe; it is not the superior men or better tools. Here, it is only occasionally that work is required to be cut so finely that the workmen are allowed all the time that they desire. When this occurs, a superb result is obtained, as at the Dutch Reformed church, on the corner of Forty-eighth street and Fifth avenue, New York City. This building is a perfect gem, fully equalling, in manipulative skill, anything to be found in Europe.

22. It is surprising that work should be done so well in Vienna, with such tools as are used by the workmen. The principal stone used for building purposes is a limestone of a light-yellow color, much like the stone first quarried at Joliet, Ill., but of coarser texture. It cuts freely from the chisels and points. When rubbed down it looks very coarse, but the faces are seldom "drawed" or rubbed, the practice being to chisel a margin, generally an inch wide, then bush-hammer all the surface within the margin. This treatment is probably the best and most economical for this kind of stone. Its coarseness does not come out so

glaringly as it would if it were polished or drawed from the tool. The tools used are such as are commonly used all over the world, but of a very inferior quality of steel, and clumsy in shape. Their "mash" or hand hammers would be laughed at by our workmen. They are made of soft iron, sometimes with lead. After working with one of these a few weeks the workman wears a hole in the faces, while our hammers will sometimes last a life-time. Their wooden mallets are of very bad quality as compared with our hickory staves. The Viennese stone-cutter gets his mallets and handles turned out of one piece; the handle is twice as long as the mallet. He does not depend on either the hand-hammer or mallet, and appears rather uncomfortable when using either; he prefers the diamond-faced bush-hammer held in both hands. The employers find all tools. This is a very serious item of expense to our own mechanics, who are compelled to pay for good tools and to meet heavy charges whenever they are required to move their tool-chests, as they are so often compelled to do.

23. The stone-cutters in Vienna are divided into two classes, those who do the rough work and cut plain moldings, and those who do a better grade of stone cutting and carving. The first class generally work by the piece, working eleven hours per day, except in winter, when they work nine hours. Their wages average 2½ gulden per day—$1.25. They have no trade societies, but have sick and provident associations which take charge of the burial of deceased members, &c. The more highly skilled workmen earn from 20 to 35 gulden per week, a gulden being worth 50 cents of our money. The men commence work at 6 a. m. and stop at 6 p. m. Formerly one hour at noon was all that they were allowed for meals, though they could sit down about 8 a. m. and swallow a hasty meal. This rule still prevails with some employers, though most of them allow their workmen a half-hour in the morning for breakfast and another in the afternoon about 3 o'clock for a supper of bread and beer.

24. The stone-cutters, assisted by their employers, have founded evening schools for the instruction of those among their number who may want to learn the technical part of their business, architectural details, draughting, free-hand drawing, and mensuration. The apprentices are all invited to avail themselves of the privileges to be enjoyed in these schools. This is also common in Germany, and it is a capital idea, well worth imitating. The workmen who wish to study the best models illustrating their craft have the art and industry museums to visit, in which splendid collections of models of ancient and modern art are found.

25. We were impressed with the careful method pursued in the fine art of the stone-cutters' craft. The new merchants' exchange, now building on the *Ringstrasse*, will illustrate the system. On the grounds are a large studio and an artist's workshop. Here models are made of every piece of sculpture and carving applicable to the adornment of a building. A leading Viennese sculptor is the head and master spirit

here; under him are a number of skilful artists, who work, guided by his directions or their own taste, in stone, wood, plaster of Paris, or clay. On the occasion of our visit, all of these materials were used. The models, when complete, are sent on to the quarry or to the stone-cutters' yard, to be copied into the stone used for the building in process of erection. Finally, the sculptor puts on such finishing-touches as he may deem requisite. This care insures the carrying out of the architect's ideas, and furnishes good, artistic work, that will stand criticism. It is also very much the practice in Europe for the architects to retain the carving they design, for the façades of their buildings, as a separate contract, employing their own men to execute it, generally by the day. In fact, all those who are rich and celebrated enough insist on this privilege, knowing well that if let to an ordinary stone-cutter, unless in an exceptional case, the work will be done as poorly and as cheaply as it can be to pass inspection; that there will be no effort made to put individuality or thought into the work, without which it is soulless and valueless.

26. There is much poor work of this class done in Vienna as elsewhere; but it is only in cheap houses. With the exception of a few public edifices, the buildings of the new Vienna which has grown up since the levelling of the old walls have stuccoed fronts. This, however, has not made the stone-cutters' craft the less busy or prosperous. Even in a stuccoed building, wherever strength is required, stone is used in the prevailing Renaissance style. There are many caryatids under the balconies and window-cornices. These are nearly all of stone.

27. Within the buildings, the stair-cases are almost invariably built of cut stone, as are the landings. This is done as a precaution against fire. Although a great improvement over wood, this is not the best kind of stair-way that can be erected.

The following extract from a report of the superintendent of the London fire-engine establishment will be interesting as bearing on this point:

"No stair-case can be considered really fire-proof unless constructed either of fire-bricks, laid in fire-cement, which would be both costly and cumbersome, or of wrought iron, which, for appearance, comfort, or convenience, might be covered with slabs of slate, stone, or wood. In this atter case the real strength would consist not in the stone or covering, but in the wrought-iron framing, and such stairs, particularly if protected by plaster, which could easily be done, might safely be relied on in all ordinary fires, as the heat near a stair-case, being tempered with the cold draught from the outside, is rarely sufficient to weaken wrought iron, which only fuses at about 3,000°, and retains a considerable portion of its strength almost to the melting point."

Stone is used as a rule in Vienna. The hall-ways and passages are all laid with cement, tiles, marble, or mosaics, all of which are fire-proof.

CHAPTER III.

PAVING SIDEWALKS AND HALLS.

ENCAUSTIC TILES; MOSAIC FLOORS; WAGES; METHODS OF WORK; YORKSHIRE FLAGGING; LONDON SIDEWALKS; ASPHALT; CEMENT; OTHER FLOORING MATERIALS.

28. ENCAUSTIC TILES.—One of the most beautiful, as it is also one of the most costly, modes of paving interiors is that of laying down Minton's encaustic tiles. These are so well known that a detailed description is not needed, especially as no new improvement or novelty was shown. Indeed, the firm did not exhibit a great quantity of this kind of ware. The writer saw a better display at their agent's place at Brussels than at the exhibition.

Minton & Hollis, another English firm, showed some very highly finished wall-tiles, and a chimney-piece, designed for a hunting lodge, enriched with appropriate and most beautifully painted tiles.

The English makers are acknowledged to be at the head of this manufacture, but there are several German firms closely competing with them.

Villeray & Bach, of Luneburg, and Ernst, March & Son, near Berlin, are very large makers of encaustic tiles, together with many other kinds of earth-ware, such as garden-statues and terra-cotta. Their tiles lacked the clearness and accuracy of line characteristic of the English ware, but as a whole they presented a good appearance. The Germans aim to produce cheap ware, while with the Staffordshire firms that is a secondary consideration. A practical artisan, thoroughly posted in this kind of work, stated that the main difference between the German and English tiles arises from the fact that the tiles made in the first-named country lack the backing or extra layer of strong, close-bodied clay, which, to a great extent, keeps them from cracking or distorting through unequal contraction. This statement we are inclined to believe, after very carefully inspecting the wares in both the German and English sections. It is unfortunate that our own manufacturers of earthenware do not try to make this kind of tile instead of buying them from the European makers. That the demand for them is large in the United States is fully shown by the large sales made here by English firms of late years. Doubtless, it will take time and capital, and artistic skill must be acquired before we can take rank with the best manufacturers of other countries who have worked long and spent much money before attaining to the present great success. But should we try we should succeed, for what has been done once can be done again. It is simply a question of money, study, and labor.

29. MOSAIC FLOORS.—The real mosaic floors which we saw at the exhibition, and in the buildings lately erected or being erected in the city of Vienna, must rank next in point of beauty and first for simplicity. There is no detail in the whole process that cannot be readily grasped in a few moments, although, as a matter of course, rapidity of work comes from practice. This work is all executed by Italian workmen, of whom about one hundred and twenty-five are employed by a countryman of theirs, D'Odorrico, who, with his cousins, are the only employers engaged in this industry in Vienna and its vicinity. It is only during the last six years that there has existed any demand for this work at the Austrian capital; now he has all the business he can possibly do.

The best specimen of the skill of these people was shown within the exhibition, at the Emperor's pavilion. The vestibules of that building were laid with very elaborate designs in marble mosaic. The side-walls and the columns at the entrance were artistically adorned with ferns and bright-green plants. These heightened the effect of the mosaic floors, which, when viewed from a little distance, seemed almost to resemble some rich Brussels or Axminster carpet.

30. The principal advantages of this process are: 1. The extreme simplicity required in manipulation; 2. Its artistic value, as pictures can be made in the floor which will not very easily wear out; 3. Its cleanliness and coolness; 4. The facility of utilization of waste material, it being the refuse of marble quarries that is used in this work; all small pieces that are not available for any other purpose can be used in mosaic flooring; 5. And last, but not least, it can be used where wood is often laid down, with this great advantage over that material, that it will not conduct the flames, but acts as a preventive to their spread if a fire occurs in its vicinity. Its cost is determined by the design. A simple pattern in black and white can be laid down very cheaply; but when it is desired to introduce marbles of many colors in an intricate design, there is hardly a limit to the cost, or to its value when finished.

Security against fire is the principal motive leading to the general use of marble floors and of imitations of marble and stone, in Vienna, and in other large European cities. Modern buildings are erected with as little inflammable material in their construction as is possible.

31. WAGES AND METHODS OF WORK.—Signor D'Odorrico has brought all his workmen from Italy. He pays them from $1 to $2 per day. His contract with them also includes paying their fare home once every two years. Workmen of exceptional skill and taste often command more than $2 per day.

This employer gave every facility for inspecting his method of working, but stated that there was very little to see, the whole process being principally an exercise of skill and experience on the part of the workmen. The first operation is the preparation of the design. This is generally composed of geometrical combinations in several colors, and is made to a scale. The foundation is sometimes made of concrete, and sometimes the stone platform or landing has a panel cut into it about

an inch in depth; in either case a mixture of Portland cement and fine sand in equal parts is floated down. This can be colored if desired; for instance, red brick pounded up and mixed with the cement will make it red. The cement must be gauged, so as not to set too quickly. The pattern is marked off on the cement with thin strips of wood, or by merely drawing a sharp line in the cement with a knife or other edge-tool. The pieces of marble, broken to a uniform size, about half an inch square, are placed beside the operators in boxes, assorted as to color. These are bedded into the cement, one against another, until the pattern grows into shape under the hands of the workmen. When enough of the floor is laid, it is rammed down to make it compact and level. The concluding process is that of rubbing it all over with a stone-rubber and sand and water. This smooths and polishes it. The process of breaking the marble into small pieces, fit for mosaic, is quite a task, demanding some skill, and one that would probably be performed by machinery in this country. It is very simple, and while some men would never learn it, others would acquire the knack at the first attempt. The workman sits down in front of a wooden block having an iron top fashioned as shown in Fig. 16. It is 6 inches wide, and about 15 inches in length. The only other tool is a chipping-hammer of two pounds weight, having one square face and one square edge. The marble is first broken into pieces 2 inches square with a sledge-hammer. These pieces are placed on the sharp edge of the iron plate and broken with the chipping-hammer. When the plate is full of pieces, the workman scoops them out with his hammer upon the heap beside him. These pieces are from one-half to three-fourths of an inch square.

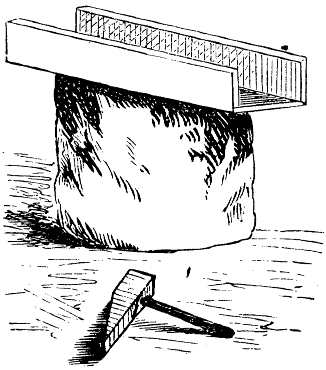


FIG. 16.—Tools used in making stone mosaics.

32. YORKSHIRE FLAGGING.—Near the South Kensington Museum, London, we saw several workmen laying down a sidewalk composed of asphaltum and cubes of gray granite. These latter were worked into the asphaltum in simple geometrical patterns, interwoven circles. The granite was broken into small pieces, each about 2 inches square. When complete, the effect was very pleasing, if only in contrast with the ordinary dreary look of the sandstone flagging so extensively used in that city. This Yorkshire flagging makes good and cheap sidewalks. The stone used is generally softer than the North River bluestone, so well known in New York, although some of it greatly resembles our flagging.

33. LONDON SIDEWALKS.—The care with which the sidewalks are laid in London is very noticeable, contrasting strongly with the careless manner in which ours are laid, except in the prominent business streets and fashionable thoroughfares of our large cities, than which

there are no better made sidewalks in the world. The London method is, first, to carefully grade the ground, sometimes using concrete to secure a firm foundation, where the soil is too soft; generally, sand spread over the levelled ground is considered good enough. The curbing is made of roughly "pene-hammered" gray granite, 12 inches wide on the top, and 6 inches high. Beside this run the gutters draining the road-way. The flagging is generally from 3 to 4½ inches in thickness. The edges are all squared, not being just pitched under, as is the practice with us. The edges are chiseled, not very elaborately, but sufficiently for the purpose, so that when the flagging begins to wear away, under the continuous traffic, the joints will continue good until it is thread-bare, if ever it is allowed to remain long enough to get into that condition. A liberal allowance of mortar is thrown down on the sand in which to bed the stones. The stones are placed close together, the inspector of sidewalks generally demanding that the joints should not be more than a quarter of an inch apart, and well filled with binding and hardening cement. The surfaces of the flags are machine-dressed, or rubbed, so that they always meet evenly at the joints. The rough stones are brought to the streets to be paved and are stacked in piles The pavers take them, preparing the edges with wonderful rapidity. It was astonishing to see the deft way in which workmen handled them. The strength with which they all seemed to be well endowed was not so remarkable as their clever knack of working them, jerking them from side to side, and, by a sudden movement, turning them over, so as to bring the edge to be squared uppermost, and placing it where anything put behind the stone will serve to keep it steady until turned again. They have a good way of splitting the flags: anything under 6 inches thick is broken in the same way that our marble-workers use to break up their slabs. Our flaggers can break a stone very quickly, but no quicker than the English workmen, who also do it more neatly, and with less waste of material. A line is drawn on the face where a break is required; this is "strummed" in with a "pitching-tool" or "nicker;" the edges are also strummed in. Then the stone is smartly struck on the back with a round-faced hammer, three blows generally breaking it neatly down the line. The writer is fully convinced that this method can be used by our own flaggers, as he has seen it successfully done with North River bluestone and with all kinds of sandstone in the brownstone cutters' yards, when cutting up sawn slabs for ashlar. Almost any kind of thin stone can be broken in this way, without the use of either wedges or plugs.

34. Asphalt pavements.—The pavements between the gutters are generally macadamized, although, as with us, stone and wooden blocks are used quite extensively. In the city proper most of the leading thoroughfares have recently been laid with a new patented preparation of asphalt. Asphalt-covered roads are a great improvement. The noise of heavy traffic is greatly diminished, and it becomes possible for pedestrians to hear each other speak without effort. At first this new system met with

the unqualified approval of owners and drivers of horses; but complaints have recently been made that "the least drop of rain renders the road so slippery that it is as bad as driving on ice, and the horses continually stumble and lame themselves." This could probably be obviated by sprinkling sand over the asphaltum. It will require very strong remonstrance to induce the authorities to cease using the new material. Its two great qualities, cleanliness and quietness under heavy traffic, will outweigh a host of minor objections.

35. Near the opera-house at Vienna a small piece of the road is laid in the same way as that just mentioned. It is the best piece of road in the whole city. Asphalt pavements for interiors are also much used in Vienna, and specimens of this work were shown at the exhibition. The finest example is seen in the fine hall of the Vienna Museum of Art and Industry. This is laid in different colors. The gentleman who did the work, M. Suppantschitch, who exhibited the certificate of merit the museum authorities had given him, kindly prepared a statement of the *modus operandi* of his business. The following is a translation of his communication, which will prove interesting as coming from a man who thoroughly understands the subject:

INSTRUCTION FOR WORKMEN ON ASPHALT-MOSAIC.—"1. Bring your caldron as near as possible to the place where you intend to lay your floor, in order that you may lay it down as hot as you can get it.

"2. Put into the caldron from 10 to 15 pounds of pitch; into the pitch, put your asphalt. This latter must be placed in the caldron when the pitch is red-hot.

"3. The asphalt must be pounded into small fragments before mixing with the pitch.

"4. After the asphalt has been in the pitch an hour or an hour and a half, stir it up well with an iron bar, broad at the end, until the asphalt is perfectly dissolved. Once this is done, fill the caldron with fine sharp sand; allow this sand to get warm for a half-hour by a good fire before mixing, so that it may of itself combine with the asphalt.

"5. Next stir up the contents of the caldron at short intervals. If the composition become stiff and difficult to stir, add a few pounds of pitch, using judgment as to how much.

"6. In laying it on bridges, thoroughfares, or viaducts, it is advisable to use more pitch, as the composition will then become more elastic. The asphalt will set without cracking.

"7. If, in stirring it, yellow vapors arise, that is an indication that the composition is ready for use. In order to prove the fact, make the following trial: dip a chip of wood into the composition, and observe if a greasy substance adheres to it; if such is the case, boil it more, until you are able to take the chip of wood out perfectly clean."

"The *modus operandi* in laying asphalt is as follows: The foreman is to see that the ground to be covered is well swept, and clear of mud, damp clay, or any such substance. He then lays down iron rails, 3 or 4 feet apart. Those rails serve as a rest for the float used to make a level

surface. One man attends to the caldron, another carries the prepared composition, in iron or wooden pails, to the operator. The workman who empties the caldron must not neglect to stir the contents of the caldron during this time, as the sand, being heavier than the pitch or asphalt, is liable to sink to the bottom, causing an uneven surface.

36. Asphalt in colors.—" In order to produce this, it is necessary to observe the following rules:

" 1. A foundation of concrete 1 to 1½ inches thick.

" 2. Float upon this a covering of black asphalt, half an inch thick, as silicates will combine easiest with this.

" 3. Put down your thin wooden strips according to the pattern you desire to produce. These rails of wood should be cemented to the floor with hot asphalt.

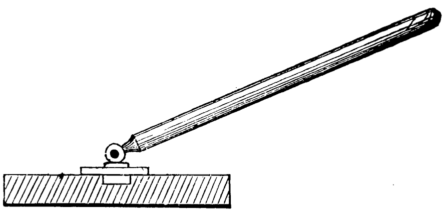
" 4. Then commence laying out the black part of the design. This should always be done first, as the black composition would be apt to soil the light colors if not laid down first.

" 5. In order to make the edges straight and even, it is necessary to smooth them with the curling-iron, Fig. 17. The wooden forms can be taken away when the composition becomes hard enough to stand without support.

Fig. 17.

" 6. Once the design is all laid, you commence polishing it with a piece of smooth sandstone attached to a handle, as shown in Fig. 18.

Fig. 18.



" PRODUCTION OF ARTIFICIAL BLACK.

40 per cent. chalk;
40 per cent. fine soft sand;
20 per cent. evaporated coal-tar.

" WHITE SILICATE.

35 per cent. chalk;
35 per cent. pure white sand, (silver-sand;)
22 per cent. pure white rosin;
8 per cent. tallow.

" First put the rosin into the caldron—it must be well melted; then put in your chalk; a half-hour afterwards mix in the sand; stir well and add the tallow.

" Asphalt in colors, red, blue, yellow, and brown, is to be boiled like the white composition, only adding the respective mineral colors."

37. CEMENT-FLOORS.—Portland cement, and compositions that resemble that material, are used for a variety of purposes in Vienna; among others, for making artificial-stone sidewalks. We also have done a little in this way in the United States, but so little that the business may be regarded as a novelty.

M. Chailly is the principal manufacturer engaged in this business in Vienna. We visited his exhibit at the Exhibition, and also the public buildings in Vienna where he had laid floors of his pavement. The railroad-depots contain his best work, the large halls and covered entrances being nearly all laid with Portland-cement pavements. The work was well done and looked likely to be durable.

M. Chailly's method is about as follows: He, like all Viennese manufacturers of patent floors, lays great stress upon the necessity of taking great pains with the foundations under his preparation. We in the United States are somewhat careless in this particular, and are apt to slight the part which will not be seen, forgetting that any defect here will affect the whole after a very short time. A dry soil is to be preferred, but if it should be moist, marshy, or a clayey soil, great care must be taken to make the foundation as firm as possible. This will be a matter in which the workman must exercise his own judgment and experience.

The first layer of concrete should be composed of one part cement and three of coarse gravel. This is laid upon the soil which is already smoothed and graded. The thickness of this layer will vary according to the nature of the soil. The second layer should be mixed in equal parts, two of cement and two of fine sand. Then a third layer, equal parts cement and sand, completes the work.

The workman finishes a piece about 3 feet wide, from the wall to the curb, before he attempts to touch another length. The first layer is to be well rammed down to make it compact; the other two layers are to be floated on as quickly as possible. It requires about four days for the sidewalk to harden. During this time it should be frequently sprinkled with water.

Spring or autumn is the best season in which to lay the cement. Summer is too dry, and winter weather is too severe. A sidewalk thus prepared will last about fifteen years.

The curbing is also made of cement. This is generally formed in a mold. The joints are made to fit into each other to prevent shifting after they are set, as shown in Fig. 19. The body of this curb is composed of three and a half parts broken stone or gravel to one-half part of cement; it is coated with a surface of equal parts fine sand and cement. Steps are made in the same way. These would serve for door-steps if they had no weight to carry. The makers of such concrete-work claim that, when properly hardened, it is stronger than stone. This is doubtful, especially as in all

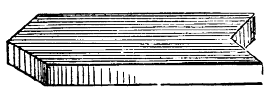


FIG. 19.—Cement-curbing.

the buildings we have seen, stone is preferred by the architects, who are the most competent judges of the relative values of building-materials.

38. It is impossible, without filling a volume, to notice all the devices shown at Vienna by various nations, chiefly, however, by Austria and Germany, for covering the floors of hall-ways and corridors, or for making sidewalks.

There were tiles made of gypsum, with inlays of various colors, which could be scratched out with one's finger-nails; tiles made of cement, with fragments of marble mixed in them; tiles of slate; tiles of common red clay; but there was not a single exhibit of a real marble floor, that we could discover. Here we have an advantage; we can quarry, saw in slabs, and fix into their places real marble tiles, native material, cheaper than the imitations can be manufactured and laid.

Bricks are very often used for sidewalks in Europe, and make admirable sidewalks. Common red brick does well, but the glazed brick, also made by our manufacturers, does better. The principal precaution to be taken by those who wish to try bricks is to look well to the foundation of the proposed sidewalk before laying down the pavement.

CHAPTER IV.

CEMENT, STUCCO, AND TERRA-COTTA.

STUCCO, ITS USE IN VIENNA AND LONDON; USE OF PORTLAND CEMENT; AUSTRIAN CEMENT; STYLE OF VIENNESE BUILDINGS; TERRA-COTTA, ITS HISTORY AND VALUE; IMPROVEMENTS IN MANUFACTURE; WORK OF THE ART-SCHOOLS.

39. The most noticeable contrast between our methods of building-construction and those in vogue in Europe arises from the fact that we use stone, bricks, iron, and wood for our fronts, while there they use, in addition, other materials which we do not generally use, such as concrete, cement, stucco, and terra-cotta.

A traveller who for the first time visits Europe, can scarcely believe that the magnificent fronts seen in some cities, as in Vienna, are not constructed of stone. The stucco with which they are plastered is made to imitate stone so perfectly that it is no wonder that he is at first misled, and that he should, when undeceived, think it a method of building well worthy of introduction into his own country, forgetting that it is still a novelty, and a deception quite as much as is brass jewelry made in imitation of gold.

No one should say dogmatically that we should not use stucco, or that it is not a good building-material when used under proper conditions. The Exhibition-building was an excellent illustration of its judicious application. Built for a temporary purpose, it was desirable that it should be made sightly and ornamental, and at as little expense as possible. Stucco was the very thing in this case, cheap, capable of being rapidly put up and readily pulled down. For this purpose it was better than stone. The use of stone was out of the question; it would have cost too much, and would have taken too long in preparation. This is a specially good illustration of the case in which a cheap imitation could not be deemed an attempt at imposition. But we cannot say as much for all the stucco which the Viennese have put upon other buildings. To adopt all their cunning methods of making imitations appear better than the real, would demoralize both our workmen and their employers. This we too often do, and it is done in every country in the world in which modern civilization has tended toward the production of shoddy, that rank weed which chokes real and honest progress.

The beautiful part of the city of Vienna is of recent construction, dating from the levelling of the old ramparts and the laying out on their site of the fine boulevard known as the Ringstrasse. In this fact may perhaps be found the key to the motive for the extensive use of

cement in building. The moneyed men began to pull down and to rebuild too freely, as perhaps recent financial panics have proven. This work became a means of speculation. Although stone is very cheap in Austria, in comparison with the prices paid here, it was too expensive for the stock-companies and speculators who were anxious to get rich quickly. They are compelled by the fire-laws to build solid and heavy walls. This could be done with the huge, cheap bricks manufactured outside the city, but the fronts needed covering up; cement-stucco was precisely the thing needed to make elegant edifices of very rough and common-looking brick-work. Owners could demand high rents while their buildings continued to wear well. This they did not fail to do. The buildings had not been erected long enough to prove that they would last well; they have already been mended, scraped, and repainted. This fact is sometimes used as an argument in favor of stucco: "It can always be made to look new and bright, at small expense, with a little scraping and a coat or two of wash."

40. Ten years ago, stucco had reached the zenith of its popularity in London, whole districts being covered with stucco-fronted houses. Suddenly public opinion veered around completely. Now, it is very seldom used, where formerly thousands of houses had been fronted with it. The reason for this sudden change in public sentiment is easily learned. The immediate cause of the disuse of stucco in London was the attempt of some of its advocates to induce the House of Commons to vote a large sum of money to be used in building some of the public buildings at South Kensington, where it was proposed to use stucco very extensively. This proposition brought down a storm upon the heads of its advocates. The truth came out. Instance after instance was adduced to show that, after a few years, it fell to pieces unless continually mended and painted. The money was not granted to build in stucco. The capitalists who had first used it began to tire of it. Their turn was served. They had run up fine-looking houses at the West End to meet a growing want felt seriously in London a quarter of a century ago when the wealthy people of that great metropolis began to move westward. The capitalists had charged high rent on short leases, as the Viennese are now doing. They began to be ashamed of the shoddy-looking places they had formerly advertised as "elegant and desirable mansions." Time had quickly made havoc with their shams. Now, whole rows of these buildings are pulled down, as the leases expire, and good brick and stone houses are erected in their places. Still, stucco had paid, and paid magnificently, as is indicated by the immense increase of the income of the Marquis of Westminster, the principal owner of these buildings. There was another effect produced by this rush into speculative building. The builders, foremen, and workmen became so demorailzed by their continual employment in the building of shams that they grew reckless, and, to make a larger profit for themselves, put less cement and more sand into the composition, so that, at last, it would

hardly hold together long enough to permit them to take away the scaffolding. The Viennese may not have reached this stage yet, under the eye of their police, the power of these officials being greater and more freely exercised among the Austrian and German peoples than it is in Anglo-Saxon communities; but there is little doubt that they "scamp" their work in the many corners, and run moldings carelessly. Sometimes a member will be a half-inch wider at one end than at the other, and cracks appear all over the fronts, looking as if a sharp frost would open them, dropping huge flakes upon the heads of those beneath. But it is at the back of the houses that bad work can be most readily found. We have, from our window, seen the occupants of the room opposite, on the other side of the court-yard, dislodge a yard or two of stucco cornice, fearing that, if left, it might fall upon the head of some unlucky person beneath. This is a bad material to use in parts of the United States where the mercury sometimes falls as low as 15° or 20° below zero.

In the course of our inquiries, it became necessary to visit the cement manufacturers and dealers. They, one and all, as was quite natural, said, "This is a most excellent, indeed, the very best material to use." They were in harmony on this point; but each claimed to make the very best cement in the market; his neighbor's being invariably defective in some important particular.

41. USE OF CEMENT.—The directions for using cement, and other particulars gleaned from them, may prove useful as a means of comparison of our own cements with theirs. The only efficient test, however, is to apply it experimentally, and await the effects of time and weather. Testing by weights and pressure is by no means reliable, as specimens of the same material, prepared under, apparently, precisely similar conditions, will often show most astonishing dissimilarity of results, when thus tested.

It is to be observed that the English Portland cement is generally taken as the standard of comparison, and of the numerous kinds manufactured there, that of I. C. Johnson & Co. is generally considered to rank among the best. This firm exhibited cement at the exposition, having sent it previously to but one exhibition—that held in Havre in 1865, where they were awarded a gold medal. Accompanying their exhibit at Vienna were printed statements of its properties, and directions for using it. Extracts from these directions are here given:

"This article is of a gray stone-color, and does not require any coloring more than it possesses in itself; this quality renders it particularly suitable for stuccoing the outside of public buildings, as well for ornamental as for plain surfaces.

"The French and Dutch government engineers, as well as the English, have subjected the English Portland cement to very severe tests, and have established the fact that, on account of its great binding power, durability, and hardness, it is indispensable in all maritime works.

During the last five years, 20,000 tons of I. C. Johnson & Co.'s Portland cement were used for the harbor at Havre.

"In analysis, the chemical composition of I. C. Johnson & Co.'s Portland cement may be stated as follows:

Lime	49.80
Alumina	11.30
Silica	18.60
Iron	17.90
Magnesia	.70
Water	1.70
	100.00

In mixing—

"Use clean water, and mix to the consistence of common mortar.

"The sand to be used with Portland cement should be quite clean, free from all earthy substance, and sharp.

"The bricks, or the work on which Portland cement is used, should be first well wetted, and when the cement has commenced setting, it should never be disturbed, as it cannot be renewed.

"For ordinary stuccoing, the walls should be well cleaned and wetted; for the first coat, three to four parts of coarse river-sand to one of cement may be used; and after this is well hardened, for the second coat, to finish off, finer sand may be employed, three parts to one of cement. Such work, if neatly jointed, bears an exact resemblance to Portland stone, but it is better calculated to resist the weather than the stone." [?]

"For moldings, equal parts of cement and sharp sand should be used.

"It is admirably adapted for flooring in any situation where a stone floor is desirable. The ground must be first well rammed and levelled with broken stone; then the paving can be filled up to the required thickness with one part of cement to three or four of shingle or crushed bricks; it must then be finished off with a steel float; or, if the pavement is out of doors, a wooden float should be used. Another mixture for paving is to put two layers, first one of four or five parts of coarse gravel to one of cement, which should be overlaid with one-inch covering of equal parts of cement and sand.

"For reservoirs, gas-tanks, &c., use two parts of sharp sand to one part of cement for the brick-work, and coat the inside with a mixture of two parts of cement to one of sand, about an inch in thickness; or, take pure cement.

"For coal-pits or other places where the water is to be dammed back, the cement should be used with less sand than in other cases, and sometimes it may be better to use it without any sand.

"For breakwater and harbor works, as at Dover and other places, blocks may be formed in frames by mixing six parts of coarse gravel with one of cement, into which mass may be inserted about one-fourth

of the whole bulk of rubble-stone; the mixture will then be about eight to nine parts of gravel and rubble-stone to one part of cement. These blocks become hard and durable, and will resist all decomposing influences of the sea or of the atmosphere.

"If a fine surface is required for the blocks, to make them appear like stone, for facing breakwaters, &c., the sides of the mold should first be plastered about one inch in thickness with a mixture of half cement and half sand; the interior of the block, of course, is filled up as before.

"For castings, pure cement should first be put into the mold, and then filled up with one part of cement and two or three parts of broken stone, or clean, sharp sand; it must not then be disturbed until quite hard."

42. Saullick and Curti are the two principal manufacturers and dealers in the cements used in Vienna. Alexander Curti has the contract to supply the Vienna water-works with 2,000,000 barrels of cement and hydraulic lime. This gentleman intended to exhibit at the Exhibition a tower built of his cement, but owing to a defective foundation his tower had to come down. The cement of this firm is a good article, notwithstanding their bad luck in this instance. Tall & Co., an English firm, whose specialty is the construction of houses of concrete, used Curti's cement in building the house erected behind the machinery-hall. This was the only instance in which the cement was used at the exhibition.

Saullick's Perlmoor cement is very much used in Austria. It is very fine, almost if not quite as good as the best Portland cement. It has been subjected to severe tests, and to analysis, as the following translation of the report of an eminent German chemist indicates:

REPORT ON CEMENT MANUFACTURED BY SAULLICK, AT PERLMOOR, NEAR WORGEL, TYROL.

43. "Mr. Saullick handed me, several months ago, a few samples of his cement.

"My assistant, Mr. Wagner, tested these samples thoroughly in my laboratory. As there have been executed in my laboratory two other analyses of English Portland cement, one by Dr. Hopfgarten, the other by Dr. Feichtinger, I am able to compare the ingredients of Mr. Saullick's cement with them, and the result is as follows:

		English Portland cement.		Saullick's cement.
		Tested by Hopfgarten.	Tested by Feichtinger.	Tested by Wagner.
Soluble in hydrochloric acid.	Water	1.00	0.96	0.50
	Lime	54.01	54.40	58.50
	Magnesia	0.75	0.86	2.55
	Oxide of manganese	Trace.	....	0.30
	Oxide of iron	5.03	5.05	5.60
	Alumina	7.75	7.36	4.75
	Carbonic acid	2.15	2.80	0.50
	Sulphuric acid	1.00	1.12	2.10
	Phosphoric acid	0.75	Trifling.	....
	Potash	1.10	0.86	0.95
	Soda	1.66	1.76	0.75
Insoluble in hydrochloric acid.	Oxide of iron	....	....	....
	Clay	....	0.37	....
	Flint-dust	22.23	23.72	18.60
	Clay and sand	2.30	....	2.35

"From this comparison it will be seen that Saullick's cement contains a little more lime and less flint-dust than the English Portland cements, but, on the whole, it shows a great similarity to them in composition. As we are well aware of the fact that two cements of the same chemical composition may, nevertheless, possess quite different adhesive powers, *i. e.*, whether they are united closely or loosely, a mere analysis of the cement does not satisfy the mind regarding its quality.

"Former trials have proved that the physical condition and the chemical composition of the clayey substances exercise the greatest influence on the quality of the product which is obtained by the "glowing" of the natural and artificial mixtures of clay and carbonic acids, and which are called hydraulic limes or cements. The clay of the Medway River, which is used for the manufacture of Portland cement, contains, in 100 parts flint-dust—

Clay	17.00
Alkali	2.08
Soda	3.00
Oxide of iron	21.06

While the common hydraulic lime, in 100 parts flint-dust, contains less than one-half these quantities of clay and iron.

"For this reason I had sent to my laboratory, by Mr. Saullick, some unburnt cement stones, in order to investigate thoroughly the contents of the contained clays. The stone is very uniform in its formation, and, during the process of analysis, emits a bituminous smell, and yields ammoniacal vapors.

"In hydrochloric acid, 78.03 per cent. dissolves, consisting of—

Carbonate lime	72.15
Carbonate magnesia	3.25

Oxide of iron	1.00
Clay	0.50
Water	1.40

and 20.4 per cent. remains as an insoluble precipitate in the acid; this is, therefore, the clayey substance of the stone. Now, this clay contains, in one hundred parts flint-dust—

Clay	17.03
Potash	4.08
Soda	3.08
Oxide of iron	9.06

"If we compare the composition of the clay of Saullick's cement-stone with that of the river Medway, the result is reached that these clays, in their proportion of flint-dust and clay, are equal, and that they only differ in proportions of alkalies and oxide of iron.

"There is yet an important feature for the Portland cement, namely, its adhesiveness—the force by which the particles adhere to each other, and which is indicated by its density. While some of our common light cements in the ground condition weigh 45 to 50 pounds per cubic foot, a cubic foot of Portland cement weighs 83 pounds. The Saullick cement weighs 83.47 pounds per cubic foot, and is therefore similar to Portland cement in this important particular.

"Dr. MAT. PELTENKAFER."

It must be borne in mind that, in Vienna, there is an abundance of good sand from the valley of the Danube. This is an important point, as cement is very seldom used without mixture; hence, the cement that will mix well with sand, without losing its adhesive power, is commercially the best.

The process of mixing and using is the same, or nearly the same, as that given above, in the "directions for using," by Johnson & Co.

If, at the Centennial Exhibition to be held at Philadelphia, a collection of the native cements and hydraulic limes of the United States could be shown, with a carefully-prepared statement of the qualities possessed by each, and of the points of difference between them and the best European cements, the exhibit and statement would be of great practical value.

44. The Viennese have been most fortunate in the architects who have designed their modern buildings. The favorite style—the Renaissance—allows a wide scope for the introduction of sculptured ornament and rich molding. These adjuncts have been freely used, but with good taste. Not a little of the admiration elicited from visitors to the Austrian capital is largely due to the beauty of the street façades. The buildings have a general uniformity, but vary in their details. Though leaning to the French school, the Viennese have given to the Renaissance a tone all their own. Their interiors are, to the writer's taste, much more beautiful than their exteriors.

All their modern public buildings, such as the opera-house, the new museums, Votive church, the palace of the archduke, the new exchange, the barracks, &c., are built either of stone or brick. This would indicate that the authorities have but little faith in stucco.

45. In all stuccoed buildings where strength is required, stone or some other strong material is used.

The chief points urged in favor of stucco are, first, its cheapness as compared with stone or pressed-brick work, and consequently the facility it gives for applying at small cost what would be enormously expensive if wrought in the costlier materials; secondly, the ease with which it can be cleaned and repainted when it is weather-stained.

Garden-houses, statues, ornamental curbing, brackets, fountains, &c., are made of cement. Very much of the so-called patent stone is nothing more than cement, sand, and a little coloring-matter. There was a large exhibit of the above-mentioned articles, made chiefly in Austria and Germany.

46. There was also exhibited a large collection of a much finer and more durable material, one that is no imitation, but which may, of right, be considered as a building-material and as an artists' material as much as stone, wood, or iron—terra-cotta. This is a product that it would pay well to manufacture in the United States. A market much greater than at present exists would readily be found for really good work among our own people. It seems strange, when it is remembered that we make some of the most beautiful bricks manufactured in the world, that we have not developed an American terra-cotta. Terra-cotta to brick-work is what the flower is to the plant—its natural outgrowth.

It has been used since the earliest times. In the British Museum, specimens of ancient terra-cotta are shown, at least two thousand years old. In Europe the last fifteen years have witnessed a great revival of this manufacture, especially in Austria, Germany, and England. In the latter country has been built the largest building ever constructed with this material—the Royal Albert Hall.

47. The chief points of improvement made during the last decade consist not so much in the improved designs as in the system of manufacturing. The old systems of kilns are superseded by new circular ovens, based for the most part on Hoffman's plan. Coal is used instead of wood, producing a great saving in cost of fuel, the coal used being the siftings and refuse of the coal-pits. The powerful draught of Hoffman's system causes almost anything to burn strongly and evenly, while there is little if any waste of heat. Much attention has also been paid to the correction of the contraction and distortion caused by the shrinkage of the clay during the period of firing. The manufacturers have learned to allow for this, having set down for reference and guidance a scale of probable shrinkage for all kinds of ware.

48. The many art-schools and museums established by the European governments have produced a very efficient class of artist-workmen

who do the modelling and designing necessary in this manufacture, and add greatly to the value of the modern work. It is noticeable that modern art-work is tending more to a level. There are not so many leviathans of art, but there are more average artists who might, centuries ago, have been considered masters, but who to-day have so many equally talented competitors that they rate but as men of average standing.

Any one interested in the production of terra-cotta will find much valuable information in a paper read by its author, Mr. Charles Barry, architect, before the Royal Institute of British Architects. (No. 14 Sessional Papers, 1867–'68.) Mr. Barry has had great experience in the use of this material for architectural purposes.

CHAPTER V.

ARTIFICIAL STONE.

RANSOME'S STONE; HISTORY OF THE INVENTION; CHEMISTRY OF MANUFACTURE; THE LATER PROCESS; HISTORY; CHEMISTRY; BELGIAN ARTIFICIAL STONE; INCREASE OF BUSINESS.

49. The manufacturers of this article in America know more of the method of production than could be gleaned by any one at the exhibition; the only illustration of this work being a solitary specimen, exhibited in the Danish section—a medallion executed by a Copenhagen firm. Still, the manufacturing of this stone has made such rapid strides that this report would be incomplete without some reference to it.

Mr. Ransome, the inventor, makes no secret of his method, and has fully explained it in a paper communicated by him to the mechanical section of the British Association at Brighton, August 20, 1872, from which the following statement is an extract:

50. "His [the inventor's] investigation into the nature and properties of stone commenced nearly thirty years since, and he found that, with few exceptions, the hardest and most durable stones were those which contained the largest proportion of silica. After numerous attempts of combining crystals of sand with powdered glass, under hydraulic pressure, and uniting the mass by partial fusion, and after having exhausted the combinations of these substances with the various cements, it occurred to the author to substitute a concentrated solution of silicate of soda or potash for the other cementing materials he had previously employed.

"This solution of silicate of soda or potash being mixed with sand and pressed into a mold formed when dried a very hard stone, having a close and uniform texture, but which, however, disintegrated upon being exposed to moisture. The next step was to submit the compound to the action of heat, when the free alkali of the cementing silicate combined with an additional quantity of the silex of the sand, and produced an insoluble silicate, unaffected by moisture. In the course of time, however, the efflorescence of a salt was observed to form on the surface of the stone in buildings where it had been used. This for the most part proved to be sulphate of soda, which existed originally in the soda-ash used in the manufacture of the silicate. This objection was removed by treating the solution of soda with caustic baryta before using it in the preparation of the silicate.

"Such, in general, were the results the author had obtained by the year 1859. * * * * * *

51. "The process of the manufacture of the solution of silicate of soda has been so fully and frequently described in various scientific journals, that the author considers it unnecessary to do more than simply allude to it here. Ordinary flint-stones are subjected to the action of a strong solution of caustic soda in cylindrical boilers or digesters, under steam-pressure of from 60 pounds to 80 pounds to the square inch. Under these conditions the flint is rapidly dissolved by the solution of caustic soda, and silicate of soda in solution is produced, which, after being discharged from the boiler, is concentrated by evaporation to a specific gravity of 17000, and contains about 66 per cent. of silicate, 33 per cent. of soda.

"In manufacturing the stone, the silicate is thoroughly incorporated with clean, dry sand, and other suitable siliceous or earthy ingredients, in a mixing-mill specially constructed for the purpose, when the compound assumes a stiff, pasty consistency, is readily pressed into molds of any required form or pattern, and is capable of receiving and retaining the most delicate impressions. If, now, the mass be allowed to dry gradually, at an ordinary temperature, it will become hard and to all appearance a perfect sandstone; but inasmuch as the several particles of sand, &c., are combined together by a soluble silicate, if exposed to the action of water the silicate will soon become redissolved, the sand and other ingredients will be set free, and the mass entirely disintegrated.

"The next problem was to determine how to convert the soluble silicate of soda into some insoluble silicate, which should possess the properties requisite for the formation of a good, hard, compact, and durable stone, without the action of fire-heat, which had been found so inconvenient and expensive in its application in former methods.

"In the year 1861, in consequence of the premature decay of the stone of the houses of Parliament, a committee was appointed by the government to examine and report on the causes of such decay, and the best means of preserving the stone from further injury. The author, in common with others, was summoned to give evidence on the subject, having for some years previously been engaged in working a process, patented by himself, for preserving stone, by first saturating it with a solution of silicate of soda, and afterwards applying a solution of chloride of calcium, which immediately decomposed the former and produced an insoluble silicate of lime in the stone so operated upon. In order to demonstrate conclusively the efficiency of such application, he proposed to reduce a piece of stone to powder, and then by the aid of those two solutions to reconvert the powder back into a solid stone.

"The experiment was tried, and the result was so completely successful, that a patent for the manufacture of artificial stone by the employment of these ingredients was at once obtained, and arrangements were

made for carrying out the same upon an extended and practical scale. In doing so the mixture of sand, silicate, &c., when molded as previously described, was immediately removed to benches placed over open tanks, or immersed therein, and completely saturated with a solution of chloride of calcium. This operation, in cases of large masses, is materially assisted and accelerated by aid of air-pumps, &c. Double decomposition of the two solutions of silicate of soda and chloride of calcium immediately takes place, resulting in the production of an insoluble silicate of lime, firmly uniting and enveloping all the particles of which the object under treatment is composed, and a solution of chloride of sodium or common salt, which is subsequently removed by the free application of water.

52. "The foregoing is a brief history of the material manufactured by the author down to the year 1870, when he developed another process, as distinct from the last described as that is from the process explained to this association in 1859.

"It was found in practice that the process of washing so as completely to remove all trace of the chloride of sodium from large masses of the stone was open to objection. It was both tedious and expensive, especially in localities where there was a difficulty in obtaining a good supply of tolerably pure water at a reasonable cost.

"The author then conceived the idea of obviating this washing process by producing the insoluble silicate of lime without the formation of the chloride of sodium or other soluble salt, which would require subsequent removal. Step by step this result has at length been arrived at, and the process of manufacture thereby materially simplified, the cost of production reduced, and the application of the material considerably extended. Many gentlemen present will doubtless recollect that some years since a siliceous mineral was discovered at the base of the chalk-hills in Surrey, especially in the neighborhood of Farnham, possessing some very peculiar properties, among others that of being readily soluble in a solution of caustic soda, at a moderately low temperature. Taking advantage of this peculiarity, the author commenced a series of experiments in order to determine if it were not possible, without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been done, and in this he has now succeeded.

53. "By this latter process he combines a portion of the Farnham stone, or soluble silica, with a solution of silicate of soda or potash, lime, (or substances containing lime,) sand, alumina, chalk, or other convenient and suitable materials, which, when intimately mixed, are molded into the required form as heretofore, and allowed to harden gradually, as silicate of lime is formed by the combination of the ingredients present. The mass then becomes thoroughly indurated and converted into a compact stone, capable of sustaining extraordinary pressure, and increasing in hardness with age,

"The chemical actions which effect these results appear to be as follows: When the materials are mixed together the silicate of soda is decomposed, the silicic acid, being liberated, combines with the lime, and forms a compound silicate of lime and alumina, while a portion of soda in a caustic condition is set free. This caustic soda immediately seizes upon the soluble silica (from Farnham) which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, which is, in its turn, decomposed by a further quantity of lime, and so on.

"If each decomposition of silicate of soda resulted in the setting free of the whole of the caustic soda, these decomposing processes would go on as long as there was any soluble silica present, with which the caustic soda could combine, or until there ceased to be any uncombined lime to decompose the silicate of soda produced, the termination of the action being marked by the presence in the pores of the stone of the excess of caustic soda in the one case or of silicate of soda in the other. In reality, however, the whole of the caustic soda does not appear to be set free each time the silicate of soda is decomposed by the lime, there appearing to be formed a compound silicate of lime and soda, whereby a small portion of the latter is fixed at each decomposition. The result is that the caustic soda is gradually fixed, and none remains to be removed by washing or other process."

"By means of the last-mentioned process, the field has been widely extended for the application of the stone produced thereby, and which for convenience, as distinguishing it from all others, has been termed 'apœnite.' It is now no difficult task to produce blocks of this material, of any form and of any size, the only limit being the means available for handling them upon the spot where they are to be employed. Moreover, the materials which form the bulk of apœnite are, as a rule, generally to be found in abundance where hydraulic or other important works are being carried on, and for which purpose the new stone is eminently suited.

"Besides possessing the several properties which have been described, the apœnite, when prepared with suitable materials, is capable of receiving the most delicate impressions, and, by the incorporation of various metallic oxides, any variety of color can be imparted to it."

54. A considerable quantity of Ransome's patent stone has been used in the rebuilding of Chicago, where it has stood the test of an American winter, having been exposed to a temperature 27° below zero without being in any way affected.

We saw a shop-front, in New Bond street, London, built of patent stone. It was pointed out to us as being Ransome's patent. Black, like all its neighbors, with London soot, it looked quite as good as any of the stone buildings around it. This front has stood ten years, and, if we had not been led to examine it closely, it would, at a cursory view, have passed with us for sandstone.

There are other specimens of patent stone built up in the pat-

entee's own country that cannot be said to have stood as well as in the instance first quoted; but former errors and defects are frankly acknowledged, while it is claimed that they have now been overcome. This is undoubtedly a good thing in a country where natural stone is scarce or very expensive; but one difficulty presents itself strongly to our mind. How is it to be mended when broken, as must necessarily happen often, just as stone will get chipped or damaged? The latter is capable of being easily restored. Can as much be said for the patent stone?

Mr. Ransome states that, "by the use of the native red oxide of iron, manganese, and other mineral substances, artificial marbles or granite of almost every description can be produced. These artificial stones, like their originals, are capable of taking an excellent polish, are extremely hard, and can be readily molded into the most elaborate forms at a very small cost."

55. This may resemble the method practiced by the Universal Marble Company, (temporary address, 9 quai de Guenart, Brussels, Belgium,) who exhibited in the Belgian section of the exposition a fine collection of mantels, table-tops, vases, &c., made by their process, and very closely imitating natural marble. But, unlike Mr. Ransome, the manager of this company's works retains the secret, as he expects to introduce his business into America himself. He therefore declined to tell any one before that event should happen anything more than he communicates to the public in advertising his work.

So much of this information as is worth recording is given below. We may add that, in the writer's judgment, they do not overstate the good points of their "universal marble." Some specimens of their imitations of costly marble were very fine, difficult to distinguish from the original, unless by the fact that the imitation was made in much larger pieces than are usually supplied in natural marble. This was done to show one of the advantages of the artificial material. The cost was not greater in proportion for 20 feet run than for a single square foot, while in the natural material every inch of increased size helps vastly to increase its value, almost doubling at every foot. This stone is used for interiors, for lining the sides of corridors, hall-ways, &c., and, in the buildings where we saw it, it produced a very rich and cool effect. It can be used, if desired, in lieu of expensive trimmings in wood. The circular of the company, left on one of their "marble" tables in the exhibition, says: "A thorough investigation and analysis of real marble has placed us in a position to produce 'ours,' as we have endeavored to imitate the formation of natural marble, and to apply a primary substance which, by crystallization, becomes as durable and hard as the very best of marble, and even in some respects surpasses it. We warrant our articles to be free from flaws or cracks, and we imitate all the innumerable different kinds of marble to perfection.

"We wish to remark here that there is a vast difference between the

imitations of marble in stucco and our article. Stucco will always crack, and is a bad imitation of marble. The advantages offered by our article, even above real marble, are the following:

"1. Cheapness, only one-third of the cost of real marble.

"2. Greater endurance under atmospheric influence.

"3. More variety in application, as we can supply surfaces straight, angled, bent, or round.

* * * * * * *

"We are always ready to furnish builders or architects, who may write to us, with prices for articles, from plan or design, with dimensions, and we can also provide buyers with the different patterns we produce, and can bring testimony from those houses, public buildings, and churches we have supplied with our work."

56. The manufacture of this article was commenced about eight years ago in Germany. Beginning with only a few workmen, they now employ three hundred at the original works, while in Brussels they employed the same number last summer in executing orders on hand for public and private buildings. This would indicate that they have a very excellent article. It certainly pleased the writer better than anything of a similar character either within or without the exhibition. The only source of dissatisfaction consisted in the fact that it was quite impossible with the means at command to learn any details of the process of manufacture, as the managers of the company declined to give any information.

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E.

METALLURGY OF IRON AND STEEL.

W. P. BLAKE.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON

IRON AND STEEL.

BY

WILLIAM P. BLAKE,
DELEGATE TO THE INTERNATIONAL JURY, GROUP I.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

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IRON AND STEEL.

INTRODUCTION.

1. This report on the iron and steel at the Vienna Exhibition in 1873 was undertaken at the request of the scientific commission of the United States to Vienna, and of the chief commissioner. The materials were gathered and the outline of the report was drawn before leaving Vienna at the close of the exhibition. It was designed to present a review of the iron and steel industry of the globe, but on the author's return to the United States the pressure of other occupation prevented giving that attention to the elaboration of the subject which its importance demands. The data are necessarily presented to a great extent in the form in which they were procured, and without attempts at generalization.

Two or more excellent reports upon the iron and steel at Vienna have been published abroad; one, by Messrs. Maw & Dredge, appears in the reports of the British commission; another, by Anton Kerpely, appears in a separate and private publication, in two parts, at Schemnitz—"*Das Eisen auf der Wiener Weltausstellung.*"

2. According to the figures given by Messrs. Maw & Dredge, the total production of all countries in pig and malleable iron is about 15,322,500 tons annually, divided approximately as follows:

	Tons.
England	6,733,000
United States	2,800,000
Germany	2,664,000
France	1,182,000
Belgium	565,000
Austria-Hungary	425,000
Russia	360,000
Sweden and Norway	306,000
Italy	74,000
Spain	72,000
Switzerland	7,500
British and South America	50,000
Japan	9,000
Asia	40,000
Africa	25,000
Australia	10,000

Mr. David Forbes,* in his report upon the progress of iron and steel industry in the year 1873, gives a total of 14,885,488 tons as a close approximation to the total production of cast iron on the globe. Professor Gruener has since published the following estimate of the total production of cast and wrought iron and steel for the year 1872. He estimates the total produce of steel in the year 1873 as about 1,250,000 tons.

	Cast iron.	Wrought iron.	Steel.
	Tons.	*Tons.*	*Tons.*
England	6, 723, 387	3, 500, 000	500, 000
United States	2, 250, 000	1, 602, 000	143, 000
Germany	1, 600, 000	1, 150, 000	200, 000
France	1, 180, 000	883, 000	138, 000
Belgium	655, 565	502, 577	15, 284
Luxembourg	250, 000	....	....
Austria-Hungary	400, 000	300, 000	49, 250
Sweden and Norway	300, 000	191, 800	12, 000
Russia	360, 000	245, 000	7, 204
Spain	34, 500	35, 600	250
Italy	25, 000	24, 000	....
Canada, India, &c	100, 000	70, 000	....
Total	13, 878, 452	8, 503, 977	1, 064, 988

The secretary of the American Iron and Steel Association, Mr. Swank, adopts the following for the world's production of cast or pig iron:

Countries.	Year.	Gross tons.
Great Britain	1873	6, 566, 451
United States	1873	2, 560, 962
Germany	1872	1, 664, 802
France	1873	1, 381, 000
Belgium	1872	652, 565
Austria with Hungary	1871	424, 606
Russia	1871	354, 000
Sweden	1872	322, 000
Luxembourg	1872	300, 000
Italy	1872	73, 709
Spain	1870	54, 007
Norway	....	20, 000
South America and Mexico	....	15, 000
Canada	....	10, 000
Japan	1871	9, 370
Switzerland	1872	7, 500
Asia	....	40, 000
Africa	....	20, 000
Australasia	....	10, 000
Total	....	14, 485, 972

3. The author's acknowledgments are due to the Messrs. Haswell, of the Austrian State Railway Works, for information regarding the operations of forging under the hydraulic press, and for opportunities of inspecting the process; to Commissioner Danfeldt and Professor Ackerman, of Sweden, and to Dr. Serlo, of Breslau. They are also due, in general, to several of the mining engineers at Vienna, and to the representatives of most of the exhibitors of iron and steel for their courtesy in replying to inquiries, and in furnishing information. The *brochures* de-

* Bulletin de la Société d'Encouragement, September, 1874, cited by David Forbes.

scriptive of the principal works, which were generally illustrated by maps and drawings, were of great service, and have been freely used in the report. Such publications are important in conveying information to the visitor at the exhibition, but particularly to jurors and reporters. They greatly facilitate the labor of reporting, and save time and trouble to both visitors and exhibitors. Several of the official catalogues were enriched by statistical and descriptive statements, notably those of Sweden and Prussia, by which the value and significance of the exhibition from those countries were greatly enhanced. The utility and educating power of an exhibition is vastly increased by the publication in connection with the catalogues of judiciously-prepared statistical and descriptive summaries of the various industries.

W. P. B.

MILL ROCK, *New Haven, Conn.*

IRON AND STEEL AT THE VIENNA EXPOSITION, 1873.

CHAPTER I.

AUSTRIA-HUNGARY.

GENERAL VIEW OF THE EXTENT OF THE MANUFACTURES AND DISPLAY OF IRON AND STEEL FROM AUSTRIA AND OTHER COUNTRIES OF MIDDLE EUROPE; TASTEFUL ARRANGEMENT OF OBJECTS; PRODUCTION OF IRON AND COAL IN AUSTRIA; DEVELOPMENT OF IRON-INDUSTRY IN CARINTHIA; SECTIONS OF FURNACES, SHOWING INCREASING DIMENSIONS AND INCREASE OF PRODUCT; DIMENSIONS OF BLAST-FURNACES IN EUROPE; INTERIOR FORMS ASSUMED BY FURNACES AFTER LONG WORKING; SECTIONS OF MARIAZELL FURNACES; RESICZA STATES RAILWAY EXHIBITION; LARGE BESSEMER INGOT; STEEL SAMPLES AND RAILS; ETCHED IRON; FERRO-MANGANESE; ROSITZER MINING COMPANY; ROTARY PUDDLER, DANK'S SYSTEM; EHRENWERTH'S ROTATING-HEARTH PUDDLER; HYDRAULIC FORGING; WIRE-ROPE TRACES.

4. AUSTRIA-HUNGARY.—The iron-industry of Austria has advanced rapidly in the last decade. It is prominent at the exhibition, and has never before been so well illustrated by ores and their products, by models, maps, and statistics. The iron and steel production of the empire is referable to three principal groups: (1) The Austrian Alps—Styria, Carinthia, Krain, Tyrol, and Salzburg; (2.) Bohemia, Moravia, and Silesia; and (3) Hungary.

The importation of iron from England and Germany has been greatly lessened, and the exportation of iron and steel has greatly increased. There has of late been a tendency to a consolidation of small and scattered private establishments into large joint-stock associations, with increased capital. The spirit of enterprise and speculation has been aroused and stimulated by the great demand for iron and steel, and by the opening of communication between the mines and coal-fields by rail and between the furnaces and a market for their products. The exhibition happens to be at about the culminating point of many speculative enterprises, and no doubt many are desirous of making the best display possible of the properties upon which these enterprises are based.

The general aspect of the ores is earthy and calcareous, in strong contrast with the ores of Sweden and America. Spathic ore is the rule, and other ores the exception. They are remarkably pure, and very favorable for the manufacture of steel. But it is not sufficient to have this abundance of ores; the fuel is equally necessary, and, unfortunately for the iron-industry of the empire, is not abundant or cheap. Charcoal can no longer be relied upon. The forests are giving out, or are required for other purposes than to be converted into charcoal. The

iron-industry is consequently being revolutionized. As in other countries, steel is rapidly taking the place of iron, and the iron-production undergoes great modification from this cause, independently of others.

5. The visitors to the exhibition interested in metallurgical industry are greatly indebted to the forethought of the *Ackerbauministerium* in preparing for distribution a very instructive *résumé* of the mining industries of the empire, and particularly for the historical view of the industries of coal and of iron and of steel in the several provinces.* This volume contains a series of descriptive memoirs from such able authorities as Baron v. Beust, the imperial and royal general mining inspector; from Ritter v. Tunner, and from Dusanek, Hofmann, and Rittler. These exhaustive memoirs are really a part of the exhibition, and they justify their liberal use in reporting upon the departments of which they treat. A free and greatly condensed translation of portions of these memoirs has, therefore, been made for the following pages, descriptive of the extent and condition of the iron and steel industry of Austria-Hungary. A few of the preliminary and later statistics are added from the recent report of Prof. David Forbes, received about the time of sending these pages to press.

There were 184 iron-mines worked in Austria in 1872, and 223 in 1873. The number of iron blast-furnaces in operation in 1871 was 115, employing 12,278 workmen; but in 1872, 112 furnaces, with 10,069 workmen. There were 129 works in operation in 1873, and the production is stated as follows:

	Vienna tons.	Value.
Iron-ore	928,982	£408,366
Pig-iron, (foundery)	45,048	459,725
Pig-iron, (forge)	286,236	2,590,133

The production of the mines and works of the Austrian Government Railway, (*Staatsbahn*,) including the collieries at Kladno, in Bohemia, and the machine-works at Vienna, has increased in the eighteen years since the properties came into the possession of the *Staatsbahn*, from (annually) 80,000 to 7,000,000 tons of coal raised; 15,000 to 70,000 tons of iron-ores raised; 7,500 to 35,000 tons pig-iron produced; 6,000 to 27,500 tons wrought iron produced; 25 to 100 locomotives.

The coal-mines of Reschitza yielded 57,800 tons in 1872, a part of which was made into coke. The three blast-furnaces are supplied with charcoal-fuel, and yield gray Bessemer pig-iron from magnetic iron-ore. The yield of these furnaces is about 34 tons of this Bessemer pig in twenty-four hours. A fourth blast-furnace at Bogsan produces about 5,000 tons of pig-iron annually. The iron at Reschitza is run directly from the blast-furnaces into the Bessemer converters, which are nine

* Denkbuch des Österreichischen Berg- und Hüttenwesens. Aus Anlass der Wiener Weltausstellung herausgegeben vom K. K. Ackerbauministerium, unter der Redaction des Ministerialrathes Anton Schauenstein. Wien, Verlag des K. K. Ackerbauministerimus, 1873. 8vo. pp. 370.

tons' capacity and three in number. The annual production is about 9,000 tons.

There are 17 puddling-furnaces and 30 furnaces for reheating and welding. There are 10 trains of rolls. The production in 1872 amounted to 12,550 tons of finished products, 7,810 tons being plates and rails, and 4,669½ tons Bessemer steel, in the form of axles, tires, rails, plates, &c.

6. As might be expected, Austria-Hungary takes the lead in this exhibition in the extent and variety of the display of iron and steel. It is at first bewildering to the visitor. He roams from one pavilion to another, seeing in each a museum of metallurgy, a mine of instruction. It is more than can be grasped in several visits, and requires repeated examinations and time for review and comparisons.

This exhibition of iron and steel from Austria and Middle Europe, being by far too extensive and bulky to be received in the main industry palace or in the courts of the building, was placed for the most part in a series of separate buildings between the machine hall and the palace. Belgium alone makes most of its display in the main building. Austria and Prussia each have separate and special buildings for displaying the products of mining industry. For Austria there are three or four buildings, of which Carinthia alone fills one, and Styria another. The State Railway Company and other wealthy corporations have exhibitions of their own.

The Prussian miners and manufacturers of iron fill the greater portion of two large buildings, one on each side of Krupp's central pavilion, erected exclusively for his remarkable collection. On entering one of these buildings, devoted to mining and quarrying, the miner feels more than ever a just pride in his vocation. He sees the miner's arms, the crossed hammers, conspicuously emblazoned in gold over the doors, and underneath the familiar motto, "*Glück auf*," "Good luck to you," and within, inscribed upon the walls, such sentiments as, "*Gott schütze das Vaterland und segne den Bergbau.*" Here, truly, the typical honest miners are to be found. The government honors their calling, and ranks it with agriculture, as at the foundation of national prosperity. But for the organized mining-systems of Europe, such a magnificent exhibition in the group of mining and quarrying could hardly have been made. As it stands to-day, it is an honor to the art, a fair child of science and industry.

The attention of every visitor is at once arrested not only by the wealth of the display in every branch of the industry of iron and of steel, but by the skill and taste shown in the arrangement of the objects. Railway wheels and axles produce little effect when tumbled loosely upon the floor; but if they are grouped in monumental masses, or are supported high in the air by light but strong steel bands, they provoke interest and admiration, even in those who know nothing of their excellencies or defects. In all of these buildings devoted to mining and

metallurgy, a liberal and generous spirit, worthy of the true miner, is shown in the provision of chairs and tables for the use of visitors, so that they may consult books of reference, or take notes at their ease. Maps and diagrams on the walls explain the position of the mines, the geology, and the method of working them. The more important of the Austrian mines are illustrated by models, showing the topography, the surface-construction, and the geological structure of the deposits, while by means of machinery part after part can be lifted off, and the whole interior of the mine displayed. The ores are sent in quantity enough to form pyramids outside of the buildings, in addition to the systematic collections within. Iron is shown in all its stages of manufacture, and the more direct manufactured products, such as rails, tires, girders, boiler-plates, &c., are exhibited in profusion. It is impossible to describe such collections, or to give an adequate idea of their value. They are complete museums of the industry, such as any mining institution in the world would be glad to take and preserve intact.

Austria-Hungary has of late years made great strides in the extent of production of iron and steel, and in the quality of the product. The importations from England and Germany are considerably lessened, and the exportations are increasing.

7. Iron and steel production.—The iron-ores of Austria are principally spathic (the carbonate of iron) and the deposits are very extensive and easily worked. The celebrated ore-mountain has beds from 20 to 40 feet thick, containing from 20 to 50 per cent. of iron, and has been worked for a thousand years without any signs of exhaustion. With such ores, and charcoal for fuel, there is no difficulty in producing a very fine quality of iron and of steel. Brown coal or lignite is largely used, and a coke made from turf is the fuel in some places. In the display made by the State Railway Company there is a complete section of a coal-seam 14 feet thick; so that, in some districts at least, there seems to be no scarcity of mineral fuel. In the charcoal-districts the great care of the forests by the government prevents their complete extinction, and with them the dependent iron-furnaces, as would be the case under the reckless policy pursued in the United States.

The production of iron-ore in the Austrian Empire has steadily increased from a total of 655,970 tons in 1867 to 1,067,753 tons in 1871. To this may be added 432,700 tons for Hungary, giving a grand total of 1,482,000 tons. The total product of pig-iron for the same year was 8,200,000 centners. The production of Bessemer steel is also rapidly increasing.

8. The iron and steel industry of the Austrian Alpine region.—The iron and steel industries of this part of Austria are found in the provinces below the river Enns, Styria, Carinthia, Krain, Tyrol, and Salzburg. Nineteen-twentieths of the ore mined is spathic ore, which, when roasted, yields 50 per cent. or more of pig-iron. The production has increased in some of the provinces and decreased in others, as will

be seen by the following tabular statement of the product at three decennial periods, with the cost per hundred-weight at the mouths of the mines:

Location of mines.	Production of iron-ores during the year—			Average cost-price of one hundred-weight at the mouths of the pits.
	1851.	1861.	1871.	
	Centners.	*Centners.*	*Centners.*	*Kreutzer.*
Austria, below river Enns	175, 150	195, 560	141, 380	32. 5
Styria	3, 221, 240	3, 876, 000	7, 537, 330	15. 0
Carinthia	1, 712, 490	2, 135, 600	3, 252, 700	20. 0
Krain	251, 930	350, 000	203, 160	37. 5
Tyrol	248, 550	271, 560	176, 860	36. 0
Salzburg	308, 040	220, 270	120, 710	18. 0
Total	5, 917, 400	7, 048, 990	11, 432, 140	18. 4

The above table shows that in 1871 the joint produce of the six provinces was nearly double the amount produced in 1851. During the last few years especially this increase has been marked. The reason of this lies not only in the increased demand for iron and in the enormous rise in its price, but the principal cause is the adoption of mineral fuel in the furnaces. The exclusive use of vegetable fuel in the Alpine region is the only reason for the non-increase of iron produce in several of the provinces and the failure to satisfy the home demand. All regions that have adhered to the vegetable fuel labor under the same difficulties. It is, therefore, Styria and Carinthia only which show an increased product and which supply the increased demand for iron in the above-mentioned provinces.

Styria and Carinthia possess two most important iron-mines—Eisenberg and Hüttenberg.* These two localities, in quality and quantity of ores, are equaled by few and surpassed by none of the other European mines. They have already been worked, according to the most authentic researches, almost two thousand years; and there is every reason to believe that the increased demand for iron will not exhaust their capacity in a thousand years to come. The raw material of the Erzberg is mostly quite accessible, and the quantity is estimated at 2,500,000,000 to 3,000,000,000 hundred-weight; that of the Hüttenberg a little less.

The celebrated Eisenberg, or ore-mountain, is well represented by a model, upon a scale of one-twentieth, made by Professor Allgayer in Leoben, and exhibited in the building of the Inneberger Company. The ore crops upon the side and summit of the mountain, and forms the greater portion of its mass upon one side. The beds of ore are interstratified with limestone and *grauwacke* overlying black slate, and are from 20 to 40 feet thick in the aggregate. A portion, mixed with lime-

* For the statistics and history of these mines, see Muchan's History of Styria.

stone, contains only 20 per cent. of iron, but the best averages 50 per cent. The old systems of transporting the ore from mine to smelting-works by means of "slides," wagons, &c., have been replaced by tram-ways and steam-railways. The cost of transportation on the railroads is $1\frac{1}{5}$ to 3 kreutzers per hundred-weight per mile. The mines of Mariazell and Neuburg have been worked a long time, and are now rapidly growing in importance. They are upon the northern vein of spathic iron. All the other iron-mines of the Alps are of minor importance, producing tolerably good ores, but in small quantities. The cost of the ores is higher, mainly on account of inconvenient methods of transportation.

9.—*Production of pig-iron.* The production of pig-iron in the Alpine provinces is of much more recent date than in the rest of the Austrian dominions. Pig-iron was produced in Carinthia in the year 1650, and in Styria it dates from 1766. According to an official report of the year 1745, Vordernberg produced in a common furnace 9,000 hundred-weight of half-refined iron yearly, with a consumption of about 40 cubic feet of charcoal per hundred-weight. In 1850, with furnaces 25 to 30 feet high, and using a hot blast of 150° centigrade, the produce per furnace rose to 30,000 to 40,000 centners, and the consumption of fuel diminished to 12 or 15 cubic feet. The 42-foot furnaces now adopted throughout the provinces have increased the product to 150,000 to 200,000 centners per annum, and 60 to 70 of coal per 100 pounds, or 9 to 10 cubic feet of charcoal. The air used in the blast is heated to 300° to 500° centigrade.

The following table shows (*a*) the produce of pig-iron; (*b*) the foundery-iron from furnaces in hundred-weight; (*c*) the price per centner in Austrian bank-notes; (*d*) the number of furnaces working:

Production of pig-iron, the price and number of furnaces.

During the year.		Austria below the Enns.	Styria.	Carinthia.	Krain.	Tyrol.	Salzburg.	Total.
1851	*a*	43, 350	945, 570	633, 860	67, 770	49, 460	50, 240	1, 799, 250
	b	1. 460	34, 110	17, 600	6, 630	12, 240	4, 670	76, 780
	c	$3. 75	$2. 86	$2. 35	$2. 85	$3. 03	$2. 84	$2. 70
	d	2	32	22	11	5	5	77
1861	*a*	40, 220	1, 439, 380	831, 810	121, 020	56, 900	59, 290	2, 548, 620
	b	940	30, 850	15, 110	6, 380	9, 650	5, 390	68, 320
	c	$3. 29	$3. 25	$2. 85	$3. 10	$3. 89	$3 74	$3. 9
	d	2	32	21	11	4	4	72
1871	*a*	39, 020	2, 437, 160	1, 263, 820	71, 010	55, 900	40, 760	3, 907, 670
	b	14, 070	105, 350	38, 290	6, 314	24, 195	2, 850	191, 069
	c	$3. 50	$3. 60	$3. 50	$3. 84	$3. 30	$4. 00	$3. 56
	d	2	31	17	7	3	2	62

The small produce of foundery cast iron shown in the above table is caused by the quality of the ores, which are more adapted for white and half-refined iron, which serves only for refineries, mills, and furnaces, but is less adapted for casting purposes. The smelting of the spathic and brown iron-ores requires from 15 to 20 per cent. more fuel to produce foundery-iron than ordinary pig-iron. In 1851 the produce per fur-

nace amounted to 24,000 hundred-weight; in 1861 to 36,000 hundred-weight; in 1871 to 66,000 hundred-weight. The exhaust-gas of the furnaces is employed for heating the blast. The introduction of this system dates from 1835, and was tried for the first time in Jenbach, in the Tyrol. Only those works erected or altered since 1872 have blasts able to work up to a temperature of 500° centigrade. The greatest difficulty under which the production of iron labors in the Alpine countries is the small amount of pig-iron turned out, and the reason is the exclusive use of charcoal-fuel. This not only makes an increase in the quantity of iron manufactured impossible, but the immense decrease of timber, and the high prices paid for it for building purposes, have created a remarkable diminution.

No changes in the fuel were made until 1870, but the scarcity of suitable coal for smelting purposes proved an obstacle. The efforts to utilize the large amount of brown coal (lignite) existing there for smelting purposes have always been unsuccessful. The first coke-furnace was erected at Prävali in 1870. One centner of coke costs in Prävali, at the mouth of the pit, one Austrian guilder. The consumption of fuel for 100 pounds of iron is 150 to 160 pounds of coke. A trial with English coke, which cost 1 florin 40 kreutzer at the works in Prävali, required 114 pounds coke for 100 pounds of iron. The produce of this first coke-furnace amounted in 1870 to 88,300 hundred-weight of iron. In 1872 the building of coke-furnaces was commenced at Niklasdorf, near Leoben, and at Zeltweg.

The fact that in 1871 the manufacture of pig-iron in the whole of Austria-Hungary amounted to 8,000,000 hundred-weight, and that the import of foreign pig-iron was 8,236,000, shows the immense deficiency in the home-produce, and that a radical change in the working system is necessary.

The annexed table, taken from "Munichsdorfer," gives the price per meiler (equal to 10 Vienna centners) of iron, and per cubic foot of charcoal, in Carinthia, from (at different successive periods) 1600 to 1872.

Price of pig-iron, and of charcoal per cubic foot.

During the year—	Price of pig-iron in florins.	Price of charcoal in kreutzer.	During the year—	Price of pig-iron in florins.	Price of charcoal in kreutzer.
1600	15	....	1840	33. 1	4. 2
1650	17	....	1850	30. 5	5. 0
1700	18	....	1860	34. 5	6. 8
1750	26	....	1866	27. 9	8. 0
1800	33. 5	3. 1	1870	42. 5	12. 0
1810	22. 1	3. 4	1871	45. 5	13. 0
1820	30. 4	3. 3	1872	48. 2	14. 0
1830	25. 8	3. 0		53. 8	14. 0

10. *Puddling-works.*—The first puddling-furnace using coal-fuel was erected in 1826, at Witkowitz, in Moravia, on English principles and by English workmen. The first gas-puddling furnace using brown coal as

fuel was erected by C. von Scheuchenstuel, in St. Stefan, near Leoben. From year to year the statistics show an increase in the numbers, so that in Austria, excepting Hungary, there existed 23 puddling-works, having 63 puddling and 36 welding furnaces. In 1851, there were 41 puddling-works, with 114 puddling and 76 welding furnaces, and 122 rolling-mills. The total produce of these 41 puddling-works amounted, in 1857, to only three-quarters of a million centners raw material, making about 150 to 160 centners per furnace per week. Influenced by the great variety and expense of the fuels, the puddling and welding processes in the Austrian Alpine regions have attained a great variety of forms, many improvements having been introduced to secure the greatest possible economy in fuel.

In 1842, gas-welding furnaces using brown-coal slack as fuel were introduced. The erection of wood-gas puddling-furnaces in 1844–'45, at Lippitzbach, in Carinthia, created quite a sensation by the favorable results attained, (3 to 4 cubic feet of wood to 100 pounds puddled iron.) Turf-puddling commenced in 1842, at Buchscheiden, in Freudenberg, and at Rottenmann, and was imitated by several minor works in Tyrol, Salzburg, and Carinthia. The step-grate for using the poor brown coal of the Alps was introduced in Prävali in 1850. The Swedish gas-puddling furnaces were introduced in Eibiswalde in 1858–'59, the fuel being a mixture of brown coal and wood.

Siemens furnaces have been introduced with great advantage. They are in general use for welding, but are only occasionally met in puddling-works, for the reason that the exhaust heat of the waste gas is used for raising steam. The double furnaces are largely in use in Carinthia, but in Styria the single ones are preferred on account of less expenditure in wages, and the better quality of the product. Hydraulic motors have been replaced by steam-power in most of the puddling-works. Upright and horizontal boilers are used, ranging from 25 to 30 horse-power. The first large steam-hammer was erected at Neuberg in 1852; it was of the Condies design, and gave a 100 hundred-weight blow. Then followed the introduction of several Nasmyth hammers with from 85 to 200 hundred-weight blows. The largest steam-hammer of the region was erected in 1865 at Neuberg, the weight of the blow being 350 hundred-weight. In 1859 the first hydraulic forge-press was erected at the Donawitz works. It has a maximum pressure of 15,000 hundred-weight.

In the wire-manufacture, which is very extensive on account of the excellence of the raw material, the factories of St. Egydi, in Upper Austria, of Feistritz, in Carinthia, and of Thërl, in Styria, should be mentioned on acount of the quality and quantity of material turned out. The tin-plate manufacture has attained considerable prominence in Wollersdorf, in Austria, below the Enns, and especially in Passhammer, in Styria. The produce of these two factories amounted in 1870 to 42,280 centners, being 23,190 centners of tin-plate, 16,140 centners of

black plate, and 2,950 centners of zinked iron. Other factories of the same description have been erected since then in Ludenberg and Trieben.

A number of puddling and rolling works exist in Styria and Carinthia, producing annually more than 200,000 hundred weight of iron. Most of these works are well fitted up and in the hands of companies and associations. A pleasing fact relative to these works is that all the operatives, from the managers and engineers down to the lowest workmen, are natives of the provinces, showing thereby that the industry has taken firm root, and that a successful opposition to foreign trade could be carried on if pig-iron can be produced in sufficient quantities and at a price low enough to compete with the imported.

11. *Rod and bar iron.*—The direct method of producing bar-iron from the ores has, till within a short period, been adhered to by several of the minor smelting-works in the Alpine countries; but now they first produce the pig-iron, and from this make bar-iron by puddling.

Bloomaries or forges were formerly numerous throughout the Alps, but the increased price of charcoal and the almost exclusive use of it in blast-furnaces have considerably reduced the proportion of bar-iron produced in this way. The first puddling-furnace in Carinthia was erected in 1828, and in 1851 the ratio of puddling-furnaces to bloomaries was as 2 to 1. In 1861 the bloomaries were reduced to one-half, and in Styria in 1871, out of the formerly legally-licensed 271 bloomaries only 100 to 110 remained, producing about 33 per cent. of the bar-iron of Styria. A great number are now totally extinct, and only those furnaces working the Lancashire method, and producing wire and fine tin-plate, are still existing. A limited number of bloomaries favored by local fuel will, of course, continue to exist. Such works are generally far removed from other furnaces, and are confined to one or two specialties.

12. *Steel in the Alpine regions of Austria.*—The spathic ores of Austria are so favorable for steel-manufacture that they are often named "steel-ores." This adaptation of the ores is the reason that as long as open-hearth steel predominated in the steel-market, the Alpine provinces, Styria, Carinthia, Krain, and Tyrol, ranked first in the steel-production. Thirty or forty years ago the production of steel in the Alpine provinces of Austria amounted to 300,000 centners, of which a great part was exported to the East and America via Trieste, and some to Germany, France, and Switzerland, leaving to the exporters a handsome profit. The produce of these provinces at present hardly amounts to 30,000 centners, and is steadily decreasing, owing to the scarcity and cost of charcoal. The first puddled steel was made in Frantschack, in 1835, by Messrs. Schlegel and Müller, who took out a patent for their method. But the real production of puddled steel in Austria dates from 1852, at the foundation of the Eibiswald and Neuberg works. This method is largely in use at the present time, and, by its cheapness, has driven the

open-hearth steel almost entirely from the market. Puddled steel is at present refined to all the different kinds of steel (Brescian, Gerb, scythe, and damask steel) formerly produced from open-hearth steel. The production of tires and railroad-iron increased the make of puddled steel, but the Bessemer and Martin processes have now superseded it. The largest steel-puddling works are those of Streitben. The introduction of puddled steel has largely increased the steel-production of Austria, but not in the same ratio as in other countries, especially in Germany. The immense advantage possessed by Austria in the excellence of her raw material, so well suited for steel-production, is more than balanced by the cheapness of labor and fuel of her German competitors, especially the Westphalian manufacturers. It is only the decided superiority of the steel which gives the Carinthian product a hold upon the market against the much cheaper Westphalian puddled steel.

Cement-steel.—The demand for a suitable steel for springs of railroad carriages, for which the cement-steel is best adapted and cheapest, stimulated the erection of works of this description in Eibiswald, and soon after in Donawitz, near Leoben. The results were satisfactory. The annual production of Donawitz amounts to 25,000 centners spring and saw blades. But in proportion to the use of puddled steel, that of cement-steel is very limited.

The *glühstahl* (welded steel) is a similar product, which is now made at Donawitz. This steel was exhibited in London in 1851, and again in Munich in 1854,* by F. Lohmann, of Witten, Westphalia.

Since 1854 there has been an annual produce of 5,000 to 6,000 centners of this variety in Donawitz. A cement-furnace for the manufacture of welded steel was erected in 1871 in Reichraming.

13. *Cast steel.*—The manufacture of crucible cast steel has long been established in the Alpine provinces; but as the old English method of manufacture, by draught-furnaces, required an immense quantity of charcoal, often as much as 50 cubic feet per centner of steel, the production has naturally been kept down. In 1851 the total production of cast steel in Austria amounted to a little more than 8,000 centners. Immense progress was effected in 1858 by introducing the Siemens furnaces in Kapfenberg. These works commenced with furnaces of 8 crucibles, each holding a charge of 45 pounds, and using 400 pounds Leoben brown-coal slack per 100 pounds steel. At present (1873) there are 10 Siemens furnaces of 18 to 20 crucibles in use. The charge is still 45 pounds to each crucible, but the consumption of fuel is reduced to 250 pounds brown-coal slack. The annual production of these works is 30,000 centners. This steel, mostly soft-tempered, is used for gun-barrels, and is partly exported to Germany. It is no longer a secret that the raw material used to produce crucible steel is regulated according

* Described by Peter v. Tunner in his book "*Der Wohlunterrichtete Hammer meister*, Graz, 1846, p. 424.

to the degree of hardness of the steel required. It consists in mixing bar and spiegel iron, (ferro-manganese.)

The inventor of this method is Alvis Obersteiner of Murau.* He has used this mixture in Austria as far back as the year 1825, and received a patent for it. From the small, unimportant iron-works of Murau it was transported to Westphalia, and from thence to Essen, forming the basis of Mr. Krupp's immense success and giant works.

A specialty of the Austrian cast steel is the "silver-steel" of Mr. Müller's works in St. Egydy, widely known, likewise, for the production of steel strings for piano-fortes.

The manufacture of Wolfram steel has been everywhere abandoned, on account of the easy oxidation of the Wolfram.

The whole production of crucible cast steel in 1871, in Austria, amounted to 85,000 centners, from 18 different smelting-works, and has, therefore, been augmented tenfold in the last twenty years. This increase would have been still greater but for the Bessemer-steel production.

14. *Bessemer steel.*—The first Bessemer-steel in Austria, and (except a few unimportant trials made in several places) the first of the continent, was produced in 1862, at Turrack, in Styria. Other works soon followed in Heft, in Carinthia, in 1864. In 1865 the works of Neuberg were opened. The production of the existing Bessemer works in the southern portion of the Alpine provinces is shown by the annexed table:

Production of Bessemer steel in Austria.

Name of Bessemer work.	Number of converters.	Annual production.			Estimated amount of present produce.	Percentage of net produce.	
		1869.	1870.	1871.		Total.	Clean ingots.
Styria:		*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*		
Turrack	3	9, 270	12, 153	22, 800	50, 000	90. 1	83. 5
Neuberg	2	62, 250	79, 598	105, 230	120, 000	89. 0	87. 0
Graf	2	63, 325	77, 563	91, 538	....	85. 5	84. 5
Zeltweg, (since 1871 in use)	2	....	....	30, 000	250, 000	......	......
Carinthia:							
Heft	2	24, 551	15, 276	62, 051	100, 000	......	84. 0
Austria below the Enns:							
Ternitz { Since July 1	2	106, 284	178, 985	386, 896	720, 000	89. 7	88. 4
Ternitz { Middle of 1871	4						
Ternitz { Middle of 1872	6						
Total	......	365, 680	363, 575	698, 515	1, 240, 000	......	......

To be added to this is the production of Reschitza, in Hungary, in 1871, 125,000 centners, and Witkowitz, in Moravia, 65,566 centners, which gives for the total produce of 1871, 889,231 centners. It is much in favor of the Bessemer method that the production of puddled steel in Austria and Hungary from 1826 to 1851 (twenty-five years) amounted annually only to about three-quarters of a million centners, while the product of Bessemer steel in eight years attained the annual figure of 889,231 centners. This is still more strikingly shown by the statistics of Styria,

* See Vordernberger Jahrbuch. 2 band. Graz, 1843.

which show that the produce of puddled steel in 1851 amounted to about 200,000 centners, while the Bessemer product in 1871 reached 250,000 centners, and may be calculated for 1872 at 400,000 centners. The charge in the different Bessemer works varies between 100 and 50 centners, and the average charge may be put down at 70 centners.

15. *Martin steel.*—The manufacture of Martin steel was commenced in 1867, in Kapfenberg, under the direct superintendence of Mr. Martin, who made the drawings for the furnaces, and supplied the workmen. This trial showed that the resulting steel was better in quality than the crucible cast steel, and that it cost less. In 1869 immense works were erected in Florisdorf, near Vienna, by Messrs. Barber & Klusemann, the patentees for Austria. These works contained 5 smelting and 3 welding furnaces, with 32 distant and 4 close gas-generators, and likewise with 11 Siemens furnaces. Martin's process is also used in Gratz and Neuberg. The charges average about 60 centners, consisting of 25 per cent. gray pig-iron, 70 per cent. bar-iron and steel scraps, and 5 per cent. spiegel iron and waste. The consumption of fuel is 80 to 100 pounds coal, or 140 to 160 pounds of brown coal, per centner of steel. The produce of the Martin's works of Gratz, in 1871, was as follows: Charges of iron, 3,205,285 centners, which produced 3,019,774 centners of steel, with a waste of 52,515 centners. The pure steel produced amounted, therefore, to 94.21 per cent., the waste to 5.79 per cent. The Martin works, in Neuberg, produced in 1871 14,368 centners of steel ingots, with a loss in raw material of 9.8 per cent., and a waste of 1.7 per cent.

16. Extent of the iron-industry in Bohemia, Moravia, and Silesia.—Iron-mining in Bohemia dates back in the remote past beyond the records of history. It is mentioned in lays and traditions as early as 677 years before Christ, and the historian Hajeck locates these early works in the vicinity of Caslaw. Many of the names of Bohemian towns are derived from the ancient mining localities. Iron-smelting was formerly carried on by Bohemian proprietors to utilize the otherwise valueless tracts of timber covering the country; but the far-spreading extensions of railroads have recently given so high a value to building-timber that iron-smelting works are forced to employ a cheaper fuel. Moravia was in advance of Bohemia in changing from charcoal to a mixture of wood and coke. Although the veins of brown coal in Bohemia are almost inexhaustible, there is still an acknowledged want of suitable coals for smelting purposes. There soon (1872–'73) will be thirteen furnaces using coke in full working order in Bohemia. They will consume at the minimum calculation 5,000,000 centners of coke to produce the same effect as 12,500,000 centners of coal. The coals of Schadowitz are the most suitable for smelting purposes. The Miroschan coals, on account of their brittleness, are neither suitable nor profitable for use in furnaces. Under these circumstances, the iron-works in Bohemia using coke will always have to rely upon a foreign supply of fuel. The Moravian iron-works are differently situated. The coal-fields of Ostran insure

an ample supply of coke-producing coal; but rich iron-ore veins are scarce. The difficulties in the rapid development of smelting-works using coke in Bohemia, Moravia, and Silesia are very formidable, but the iron-masters are determined to overcome them and to maintain the success of the iron-industry.

17. *Iron-ore Mining.*—In the year 1807 there existed in Bohemia 46 furnaces in full working order, producing 1,040 hundred weight of iron in twenty-four hours.

The following table shows the amount of iron-ores produced during 1870:

Production of iron-ores during the year 1870.

Country.	Production.	Number of mines.	Number of workmen employed.	Average price at the works.	Total value.
	Cwt.			*Florins.*	*Florins.*
Bohemia	4, 581, 582	49	1, 877	15. 3	563, 703
Moravia	1, 788, 075	18	1, 464	13. 0	234, 406
Silesia	296, 318	6	630	26. 3	45, 926
Total	6, 665, 975	73	3, 971	....	844, 035

Out of these 73 iron-works, 2 did not yield any profits and 15 suspended operations. Their joint production of iron-ores amounted to 40 per cent. of the entire produce of Austria.

About the year 1865, the product increased in Bohemia 2,184,486 centners, and in Moravia to 381,379 centners, but diminished in Silesia 66,977 centners, showing a total increase of 2,498,888 centners in the three countries. Sixty per cent. of the iron-ore comes from the Silurian districts, and the amount carried out of Bohemia forms 90 per cent. of the entire produce of that country. The principal proprietors of the iron-mines are the "Præger Eisenindustrie Gesellschaft," the Lebrow estate, the elector of Hesse-Cassel, the Prince Colloredo Metternich, and Prince Furstenberg and the State of Pilsen. The greatest mines are those of Nucier. The Chamoisit mines are worked by the aforesaid company, and the product is taken through horizontal tunnels to the Nucier Railroad. Below the level of the tunnels the transportation of the ore is difficult and expensive. The red-ironstone mines are comprised in two divisions. The eastern one embraces the Karabina Mountains, and the veins of Swarover on the left bank of the Kacier brook. The western division is formed by the mines of Jezovcin Chrbina, on the right bank of the little river Raciba. The eastern division is known under the name of Suarow works, the western as Chrbina mines. In Suarow the veins are perpendicular, in Chrbina they are horizontal. The average cost-price in the two principal works is as follows: Chrustenic, 1 hundred-weight of iron-ore, 15½ to 17 kreutzer; Krahulov, 1 hundred-weight of iron-ore, 22½ to 23½ kreutzer. The total produce of iron-ore from the mines of the Elector of Hesse-Cassel, in the year 1870,

amounted to 371,190 hundred-weight, and the average cost per hundred-weight amounted to 10.9 kreutzer. All the iron-mines of Bohemia are worked on the most approved scientific principles. In minor works the water is taken out either by windlass or by bucket, but in the more important ones pumps are employed, moved either by steam or water power. In Moravia, in most cases, the mines are a long distance from the smelting-works, and often the transportation is difficult and insufficient. The cost-price of the product therefore varies considerably. In a total production of 9,473,374 hundred-weight the price, at the mouth of the pit, ranges from 7½ to 10 kreutzer (minimum) to 18 to 19 kreutzer, (maximum.) The transportation to the smelting-works increases these prices from a minimum of 19 up to 65 kreutzer.

The ores of Silesia are mostly magnetic, red, brown, and spathic ironstones, and specular iron, yielding 23 to 27 per cent. The large ironworks of the Archduke Albrecht of Austria cover a surface of 1,229,312 square klafters, and their produce in the year 1871 amounted to 188,730 centners. The average cost-price amounted to 37 kreutzer per centner. Some of the ores were very poor, containing only 18 to 24 per cent. of iron.

18. *Production of pig-iron.*—The following table gives the quantity of pig-iron produced in the three countries during the year 1870:

Country.	Raw iron.		Total.	Number of furnaces.			
	Bloom.	Cast.		Not working.	Working.	Total.	Working weeks.
	*Centners.**	*Centners.*	*Centners.*				*Number.*
Bohemia	953, 433	320, 476	1, 273, 920	12	40	52	1, 727
Moravia	410, 611	186, 221	596, 832	....	21	21	874
Silesia	65, 910	51, 974	117, 885	1	6	7	293
Total	1, 429, 954	558, 671	1, 988, 637	13	67	80	2, 894

* Or one hundred-weight.

The production of pig-iron was, until the year 1838, effected throughout the whole of Bohemia by means of charcoal-furnaces. From this period the use of coal-fuel commenced, and a constant changing of old furnaces and adding of new ones has been going on ever since.

The cost of producing 100 pounds of pig-iron in the Silurian districts may be stated as follows:

	Fl.	Kr.
330 pounds of ore, at 20 kreutzer	0	66
45 pounds of limestone	0	2
16 cubic feet of charcoal, at 15 kreutzer	2	40
Wages	0	20
General working-expenses	0	25
Total	3	53

The steady advance in the prices of charcoal will, in the future, increase the cost of the raw material.

19. *Founderies.*—In Bohemia, casting is generally done directly from the furnaces, and the largest portion is common commercial castings. The most important foundery of Bohemia is that of Kladno, which produces the most complicated and heaviest machinery-castings. The founderies of Moravia are almost entirely employed in machinery-casting. Several works use cupolas with hot-blast. The most important foundery, that of Blansko, turns out annually 150,000 centners of castings.

The Silesian founderies are on the same principle as the Moravian, and their annual produce is about 60,000 hundred-weight of castings. The founderies of Adamsthal work up annually 46,000 hundred-weight of raw material, consuming fuel as follows: Coke, 18,000 hundred-weight coal, (Ostran,) 12,000 hundred-weight; charcoal, 24,000 cubic feet.

20. *Rolling-works.*—(1.) The works of the *Præger Eisenindustrie Gesellschaft.* These works are in Kladno, Nürschau, Wilkischen, and Josephihütte. The annual production is 700,000 centners.

(2.) Baron von Rothschilds's works at Witkowitz. The produce, mostly railroad-iron, tires and axles, sheet-iron and commercial iron, is 400,000 centners per annum.

(3.) The works of Archduke Albrecht at Karlshütte and Ustron produce 320,000 centners per annum.

(4.) Rolling-works of Prince Fürstenberg in Althütten, near Beraun and Bras, Rostok, in Silesia, and Purgletz, in Bohemia, with a joint produce of 290,000 centners per annum.

(5.) Iron-works of the Klein Brothers in Töptan and Stefanau, producing 200,000 centners annually of beams, girders, boiler-iron, and steel.

(6.) The white-iron works of Neudeck produce 80,000 centners per annum.

(7.) Mr. Bondy's works at Bubna, near Prague, produce 70,000 hundred-weight per annum.

(8.) Count Harrach's establishments. The production amounts to 28,000 centners of tin-plate, 18,000 centners of drawn wire and light bar-iron.

(9.) Two works of an unimportant character are in process of erection at Komotan and Leibnitz. Besides these large establishments, there are several smaller ones.

21. *Bloomaries and puddling-works.*—The manufacture of wrought iron was, up to the year 1865, an important branch of the Bohemian iron-industry, and there were then in operation 110 bloomaries and 28 blast-furnaces, producing more than 250,000 hundred-weight per annum. The production of Moravia failed to come up to this standard, and in 1865 it amounted to 120,000 hundred-weight. Silesia, with 28 bloomaries and 10 blast-furnaces, produced about 50,000 hundred-weight, so that the total production of the three countries during the year 1865 amounted to 420,000 hundred-weight. But since this period most of the Bohemian bloomaries ceased to work, and in 1870 only a few were in active operation, and these worked only

to utilize the remnants and scrap-iron of their founderies and rolling-mills. Most of the charcoal-furnaces possessed two to four bloomaries, which partly refined the pig-iron but never converted it into wrought iron. At the present time only those bloomaries are of any importance which produce raw material for rolling-mills, especially if the object is to produce a good quality of iron from scraps and remnants. In the year 1871 there were 116 puddling-furnaces in Bohemia, and 70 in Moravia and Silesia, making a total of 186 puddling-furnaces. The pig-iron produced in Bohemia, Moravia, and Silesia, and the remnants and scraps of rolling-mills, do not satisfy the demand of the puddling-works for raw material, so that over 2,500,000 hundred-weight of pig-iron is annually imported. In all the new works each furnace is supplied with a separate chimney. Double furnaces are only employed for the manufacture of inferior kinds of iron. The "loupes" are compressed by steam-hammers on the Nasmith principle. The works are fitted up with two pairs of rollers, but those erected during the last five years have generally three rollers placed one above the other.

The producing capacity and the consumption of material differ vastly on account of the different kinds of coal employed. The annexed table shows the results, employing Ostran coals, in the manufacture of an average quality of iron per 100 pounds rails:

Consumption of pig-iron: single furnace, 114 pounds; double furnace, 114 pounds. Consumption of coal: single furnace, 135 pounds; double furnace, 95 pounds. Weekly capacity of production: single furnace, 270 hundred-weight; double furnace, 400 hundred-weight.

22. DEVELOPMENT OF IRON-INDUSTRY IN CARINTHIA.—Among the many interesting special publications to accompany the exhibits at Vienna, the memoir of Friedrich Münichsdorfer upon the production of iron in Carinthia* is deserving of special mention. Besides a general history of the development of the iron-industry since the time of King Otto in the year 953, it gives an account of the prices of iron during the century, a tabular statement of the production for the last fifty years, and a comparison of existing furnaces with those of the beginning of this century, as respects form, capacity, extent, and economy of production. This comparison is rendered striking and instructive by a series of vertical sections of the furnaces at different periods, drawn to the same scale, presenting a complete view of the gradual development of furnaces, from the simplest form in early times to the modern furnace, with its comparatively enormous product.

During the construction of a railway a few years since, some ancient smelting-hearths, dating back to the time of the Romans, were uncovered. They consist of holes or ditches depressed below the surface of the ground and lined with fire-clay and quartz to a thickness of some 18 inches.

* Geschichtliche Entwicklung der Roheisen-Produktion in Kärnten, zusammengestellt von Friedrich Münichsdorfer, Oberbergverwalter in Hüttenberg. Klagenfurt, 1873. Pp. 36, and 14 plates.

Blast-furnaces from 5 to 6 feet high were introduced in the eighth century. They were so placed as to have a natural draught or blast. The "wolf" furnaces had a rectangular base of 4 or 5 feet, and a height of from 6 to 8 feet. A furnace of this kind at Sölling, in 1775, was elliptical in section and 12 feet high. The iron bloom was removed from the front.

23. SECTIONS OF CARINTHIAN FURNACES.—The sections which follow show the constantly-increasing dimensions of the furnaces and the economy of production. In the following descriptions of the Carinthian furnaces the numbers of the notes at the foot refer as below:

1. Kind and mixture of ore.
2. Blast.
3. Tuyeres.
4. Average production in twenty-four hours.
5. Consumption of coal per Vienna centner of pig-iron in cubic feet.
6. Per cent. of production.

The name of the furnace and the date are placed at the head.

KREMSBRUCKEN.

Last campaign, 1833.

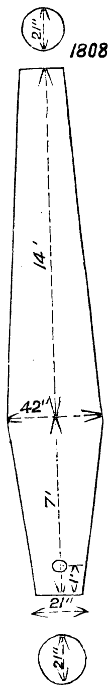


FIG. 1.

1. Brown iron-ore and ocher.
2. Two box-bellows.
3. One tuyere.
4. 62 Vienna centners.
5. 20.6 cubic feet.
6. 36 per cent.

EISENTRATTEN.

1808.

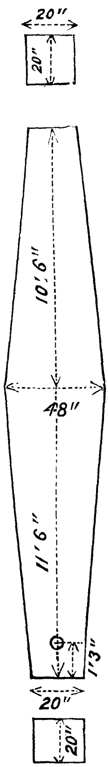


FIG. 2.

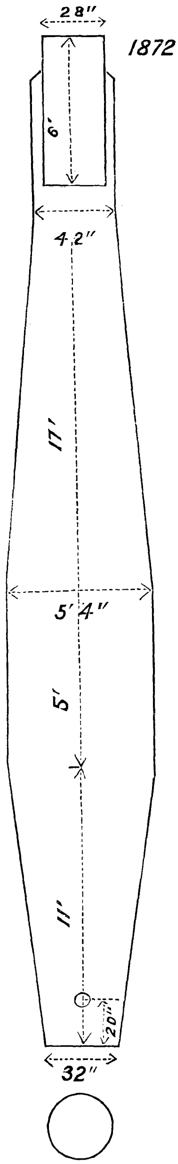


FIG. 3.

1. Brown iron-ore and ocher.
2. Four box-bellows.
3. Two tuyeres.
4. 95 Vienna centners.
5. 23.2 cubic feet.
6. 38 per cent.

1. Brown iron-ore and ocher.
2. Three cylinders.
3. Three tuyeres.
4. 118 Vienna centners.
5. 16 cubic feet.
6. 37 per cent.

RADENTHEIN.

Last campaign, 1863.

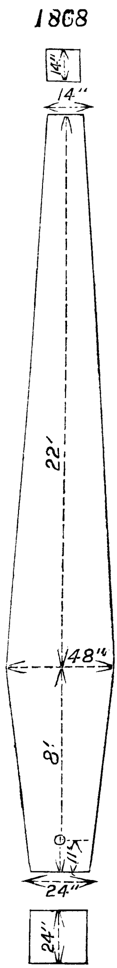


FIG. 4.

1. Magnetic iron-ore.
2. Two box-bellows.
. One,
4. 25 Vienna centners.
5. 20.3 cubic feet.
6. 30 per cent.

DEUTSCH-PONTAFEL.

Last campaign, 1847.

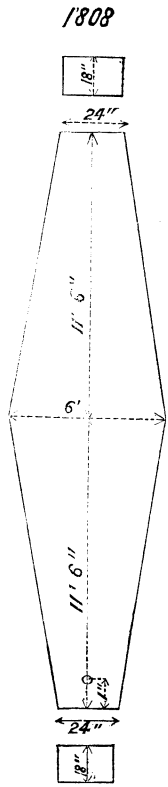


FIG. 5.

1. Red and brown iron-ore.
2. Three water-strommels.
3. One.
4. 45 Vienna centners.
5. 25.3 cubic feet.
6. 46 per cent.

ST. SALVATOR.

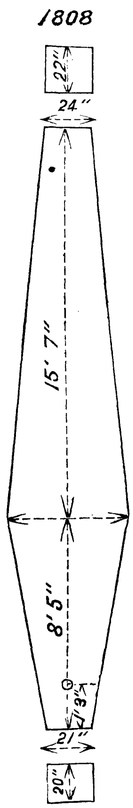


FIG. 6.

1. Brown iron-ore and spathic ore.
2. Two box-bellows.
3. One.
4. 71 Vienna centners
5. 18.6 cubic feet.
6. 40 per cent.

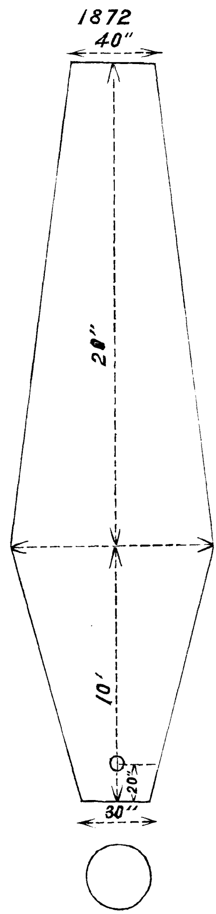


FIG. 7.

1. Brown iron-ore.
2. Three box-bellows.
3. Two.
4. 120 Vienna centners.
5. 16 cubic feet.
6. 40 per cent.

HIRT.

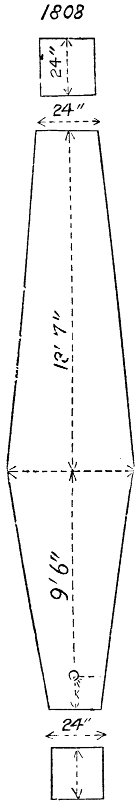


FIG. 8.

1. Brown ore and spathic ore.
2. Two box-bellows.
3. One.
4. 59 Vienna centners.
5. 16.7 cubic feet.
6. 36 per cent.

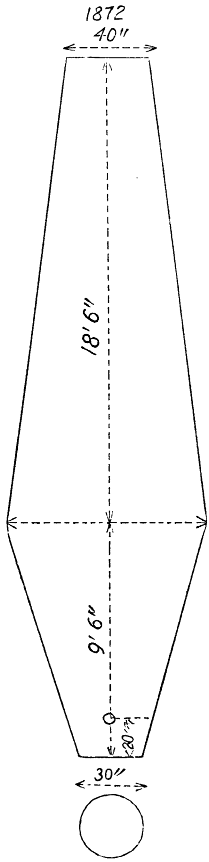


FIG. 9.

1. Brown ore and spathic ore.
2. Cylinders.
3. Two.
4. 130 Vienna centners.
5. 12 cubic feet.
6. 46 per cent.

OLSA.

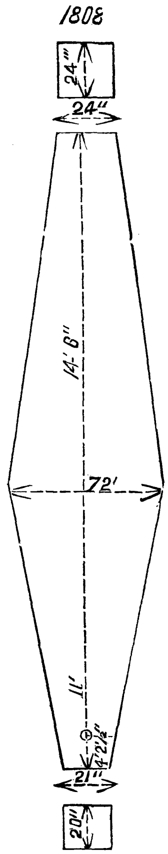


FIG. 10.

1. 4-5 brown iron-ore, 1-5 spathic.
2. Two box-bellows.
3. One.
4. 75 Vienna centners.
5. 15.9 cubic feet.
6. 36 per cent.

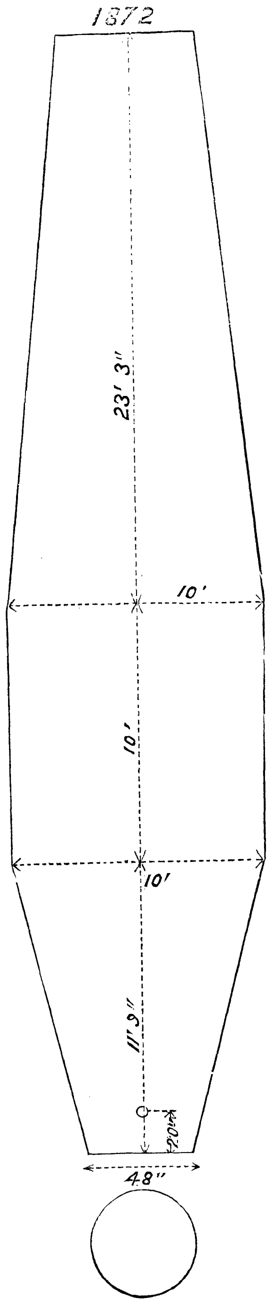


FIG. 11.

1. Brown iron-ore.
2. Three cylinders.
3. Four.
4. 275 Vienna centners.
5. 11 cubic feet.
6. 36 per cent.

FEISTRITZ.

Last campaign, 1834.

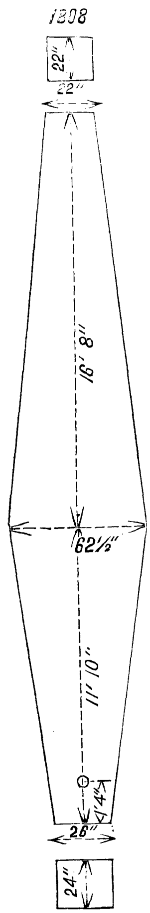


Fig. 12.

1. Brown and spathic ore.
2. Two "spitzbalge."
3. One.
4. 80 Vienna centners.
5. 10.3 cubic feet.
6. 45 per cent.

TREIBACH.

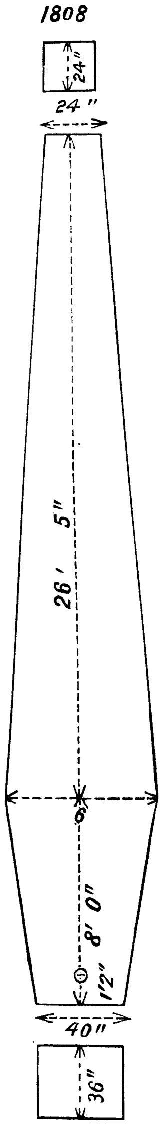


FIG. 13.

1. Brown ore and spathic.
2. Four box-bellows.
3. Three.
4. 160 Vienna centners.
5. 12.2 cubic feet.
6. 46 per cent.

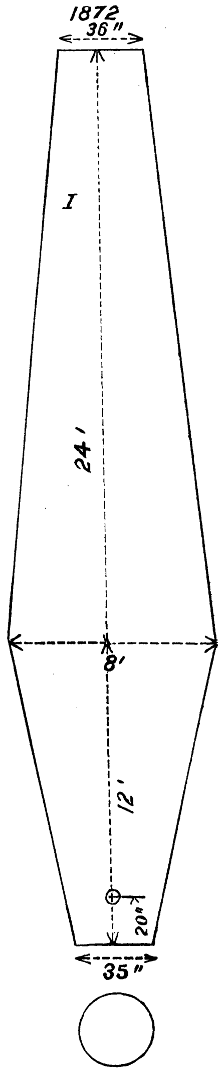


FIG. 14.

1. 91 per cent. of brown ore and 9 per cent. of spathic ore.
2. Four cylinders.
3. Three.
4. 278 Vienna centners.
5. 10.48 cubic feet.
6. 46 per cent.

1872.

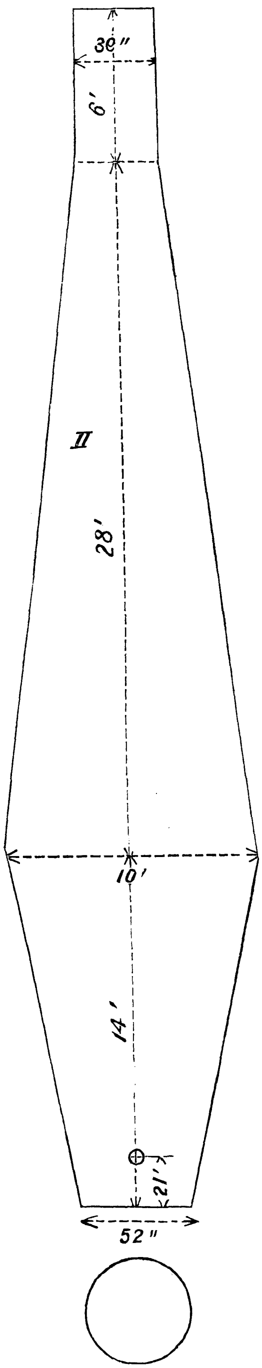


FIG. 15.

1. 91 per cent. of brown ore and 9 per cent. spathic ore. 2. Eight cylinders. 3. Five tuyeres. 4. 447 Vienna centners. 5. 7.85 cubic feet. 6. 47 per cent.

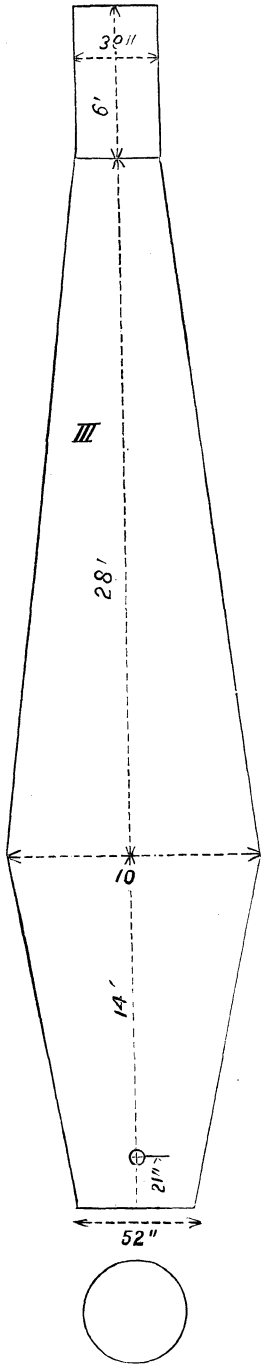


FIG. 16.

1. 91 per cent. of brown ore and 9 per cent. spathic ore. 2. Eight cylinders. 3. Five. 4. 422 Vienna centners. 5. 839 cubic feet. 6. 46 per cent.

URTL.

Last campaign, 1834.

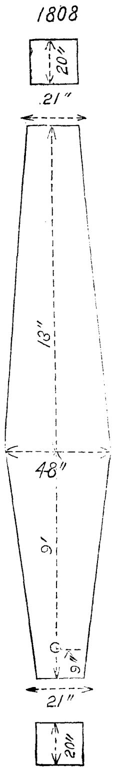


Fig. 17.

1. Brown ore and spathic ore.
2. Two box-bellows.
3. One.
4. 71 Vienna centners.
5. 21.7 cubic feet.
6. 38 per cent.

KOMPAGNIE HÜTTE.

Last campaign, 1812.

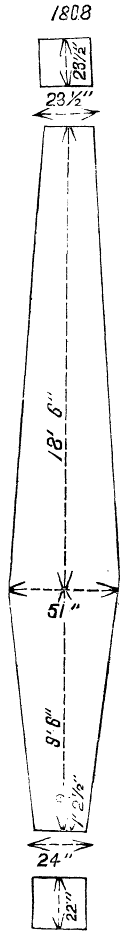


Fig. 18.

1. Brown ore and spathic ore.
2. "Schubalge."
3. One.
4. 61 Vienna centners.
5. 21.1 cubic feet.
6. 48 per cent.

HEFT.

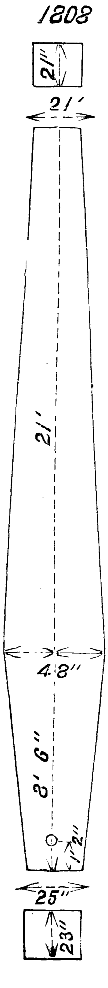


Fig. 19.

1. Brown ore and spathic ore.
2. Two box-bellows.
3. One.
4. 99 Vienna centners.
5. 12.7 cubic feet.
6. 50 per cent.

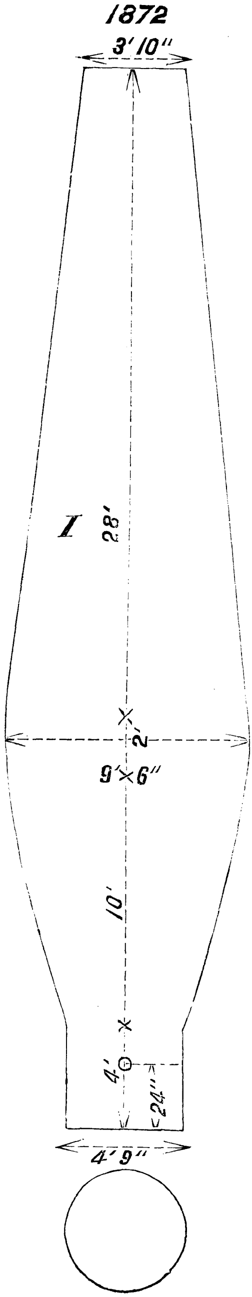


Fig. 20.

1. Brown ore and spathic ore.
2. Four oscillating, four fixed, and two horizontal cylinders.
3. Five.
4. 225 Vienna centners.
5. 9.87 cubic feet.
6. 50 per cent.

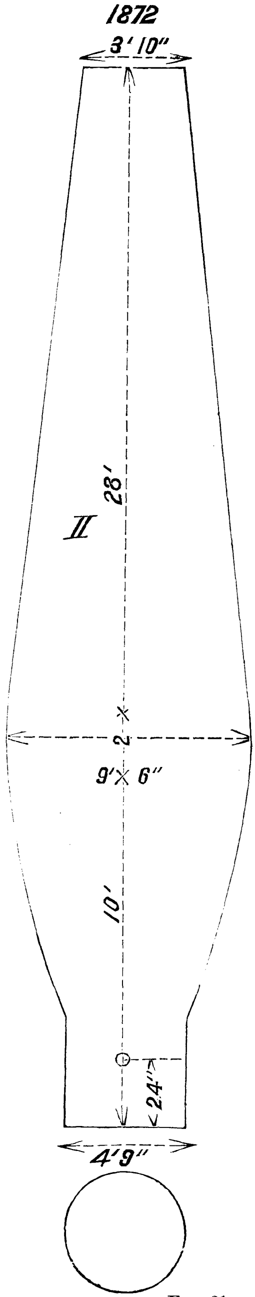


Fig. 21.

1. Brown ore and spathic ore.
2. Four oscillating, four fixed, and two horizontal cylinders.
3. Five.
4. 264 Vienna centners.
5. 9.58 cubic feet.
6. 51 per cent.

MOSINZ.

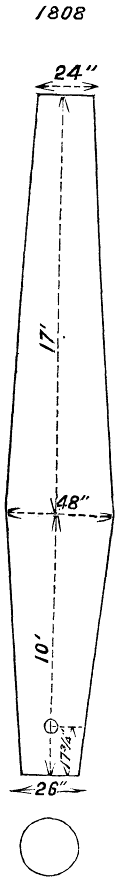


FIG. 22.

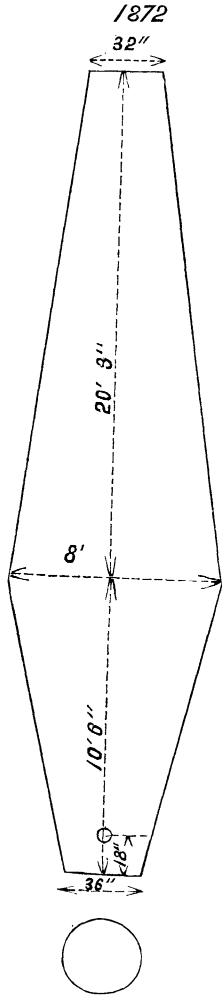


FIG. 23.

1. Brown ore and spathic iron-ore.
2. Two box-bellows.
3. One.
4. 90 Vienna centners.
5. 14.1 cubic feet.
6. 52 per cent.

EBERSTEIN.

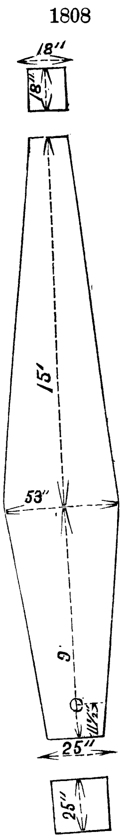


Fig. 24.

1. Brown iron-ore $\frac{1}{3}$, and spathic ore $\frac{2}{3}$.
2. Two "spitzbalge."
3. One.
4. 63 Vienna centners.
5. 16.8 cubic feet.
6. 30 per cent.

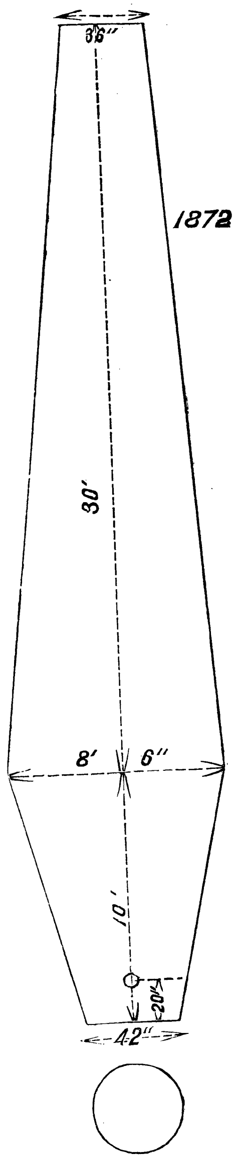


Fig. 25.

1. Brown ore $\frac{1}{2}$, and spathic ore $\frac{1}{2}$.
2. Two oscillating and two fixed cylinders.
3. Three.
4. 286 Vienna centners.
5. 9.88 cubic feet.
6. 47 per cent.

LÖLLING.

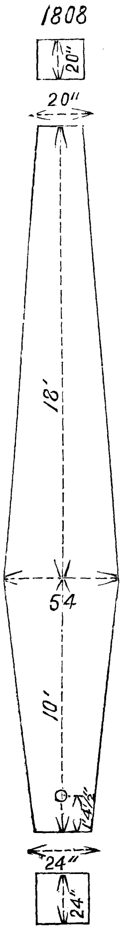


FIG. 26.

1. Brown ore and spathic ore.
2. Two box-bellows.
3. One.
4. 88 Vienna centners.
5. 11.8 cubic feet.
6. 50 per cent.

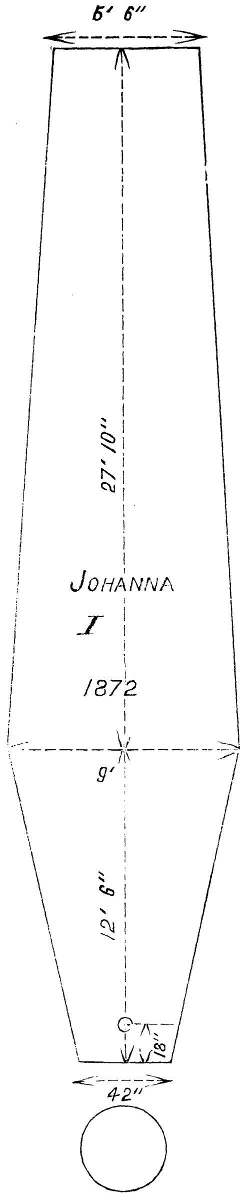


FIG. 27.

1. Brown ore 85 per cent., and 15 per cent spathic ore.
2. Two fixed, two oscillating, and two horizontal cylinders.
3. Three.
4. 293 Vienna centners.
5. 9.13 cubic feet.
6. 50 per cent.

LÖLLING.

1872.

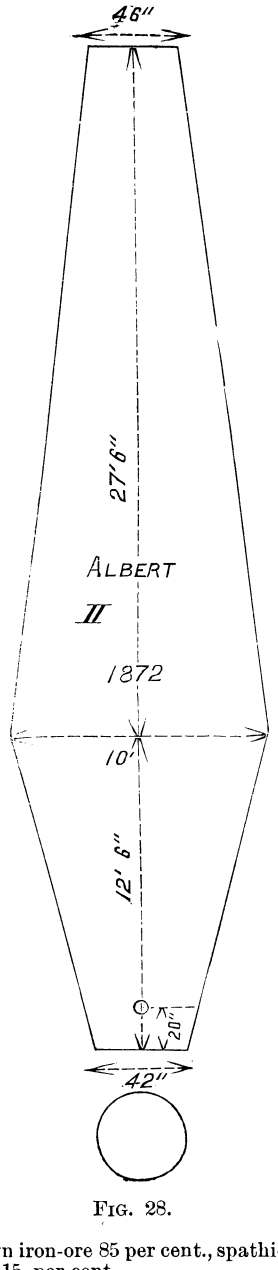


FIG. 28.

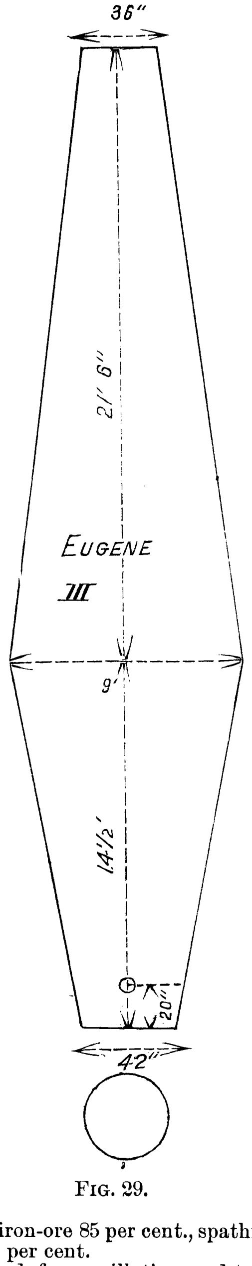


FIG. 29.

1. Brown iron-ore 85 per cent., spathic iron-ore 15 per cent.
2. Two fixed, four oscillating, and two horizontal cylinders.
3. Three tuyeres.
4. 296 Vienna centners.
5. 8.35 cubic feet.
6. 50 per cent.

1. Brown iron-ore 85 per cent., spathic iron-ore 15 per cent.
2. Two fixed, four oscillating, and two horizontal cylinders.
3. Three tuyeres.
4. 325 Vienna centners.
5. 9.39 cubic feet.
6. 50 per cent.

MINDISCH-KAPPEL.

Last campaign, 1823.

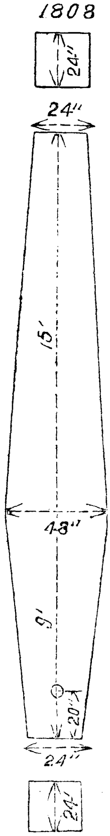


FIG. 30.

1. Red iron-ore, (hematite.)
2. Two box-bellows.
3. One tuyere.
4. 35 Vienna centners.
5. 25 cubic feet.
6. 38 per cent.

WAIDISCH.

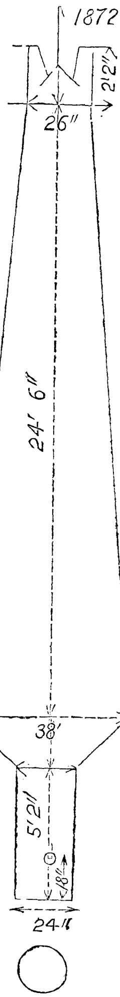


FIG. 31.

1. *Trischschlacke.*
2. One oscillating, one fixed cylinder.
3. One tuyere.
4. 50 Vienna centners.
5. 12 cubic feet.
6. 58 per cent.

WALDENSTEIN.

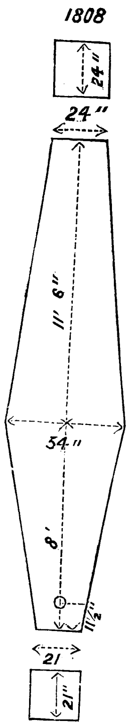


Fig. 32.

1. Brown ore $\frac{4}{5}$, spathic ore $\frac{1}{5}$.
2. Two box-bellows.
3. One tuyere.
4. 38 Vienna centners.
5. 26.2 cubic feet.
6. 30 per cent.

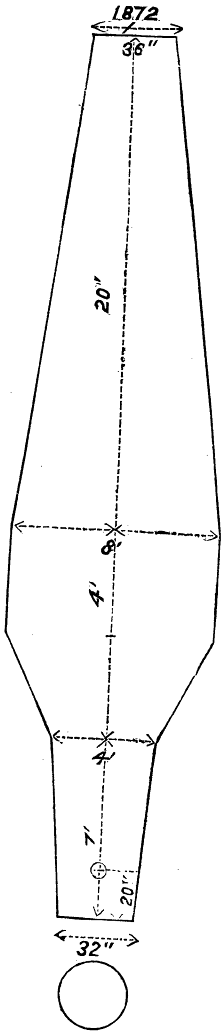


Fig. 33.

1. Specular ore, brown ore, and spathic ore.
2. Three "*wackler.*"
3. Three.
4. 115 Vienna centners.
5. 11 cubic feet.
6. 45 per cent.

ST. GERTRAND.

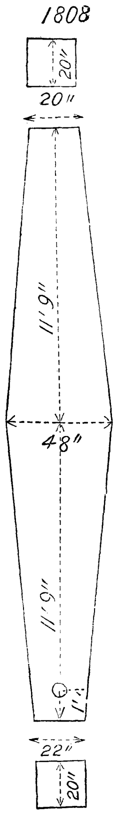


FIG. 34.

1. Brown iron-ore $\frac{3}{5}$, and spathic iron-ore $\frac{2}{5}$.
2. Two box-bellows.
3. One tuyere.
4. 57 Vienna centners.
5. 174 cubic feet.
6. 39 per cent.

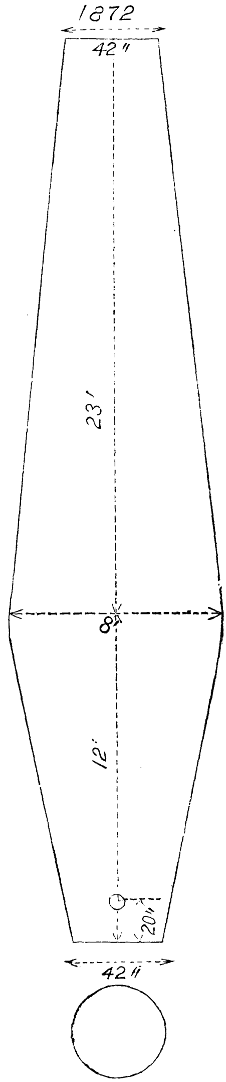


FIG. 35.

1. Brown iron-ore and spathic iron-ore.
2. Three cylinders.
3. Three tuyeres.
4. 120 Vienna centners.
5. 12.5 cubic feet.
6. 41.6 per cent.

ST. LEONARD.

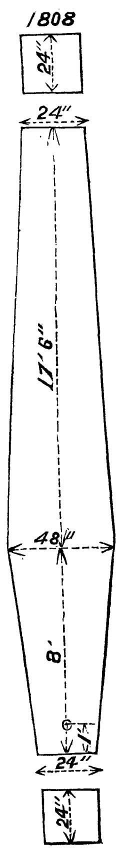


Fig 36.

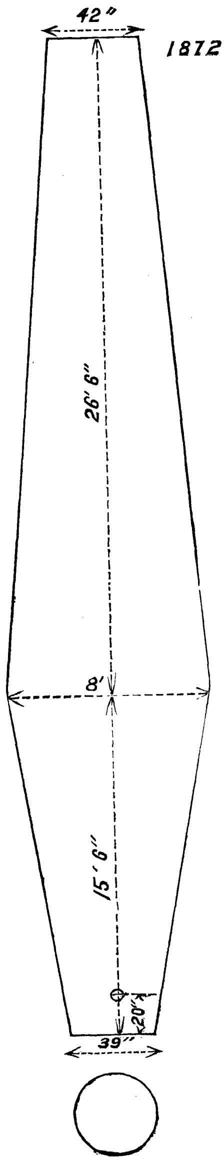


Fig. 37.

Fig. 36:

1. Brown iron-ore $\frac{2}{3}$, and spathic iron-ore $\frac{1}{3}$.
2. Two box-bellows.
3. One tuyere.
4. 53 Vienna centners.
5. 18 cubic feet.
6. 45 per cent.

Fig. 37:

1. Brown iron-ore $\frac{2}{3}$, and spathic iron-ore $\frac{1}{3}$.
2. Two cylinders.
3. Three tuyeres.
4. 132 Vienna centners.
5. 10.4 cubic feet.
6. 42 per cent.

PREVALI.

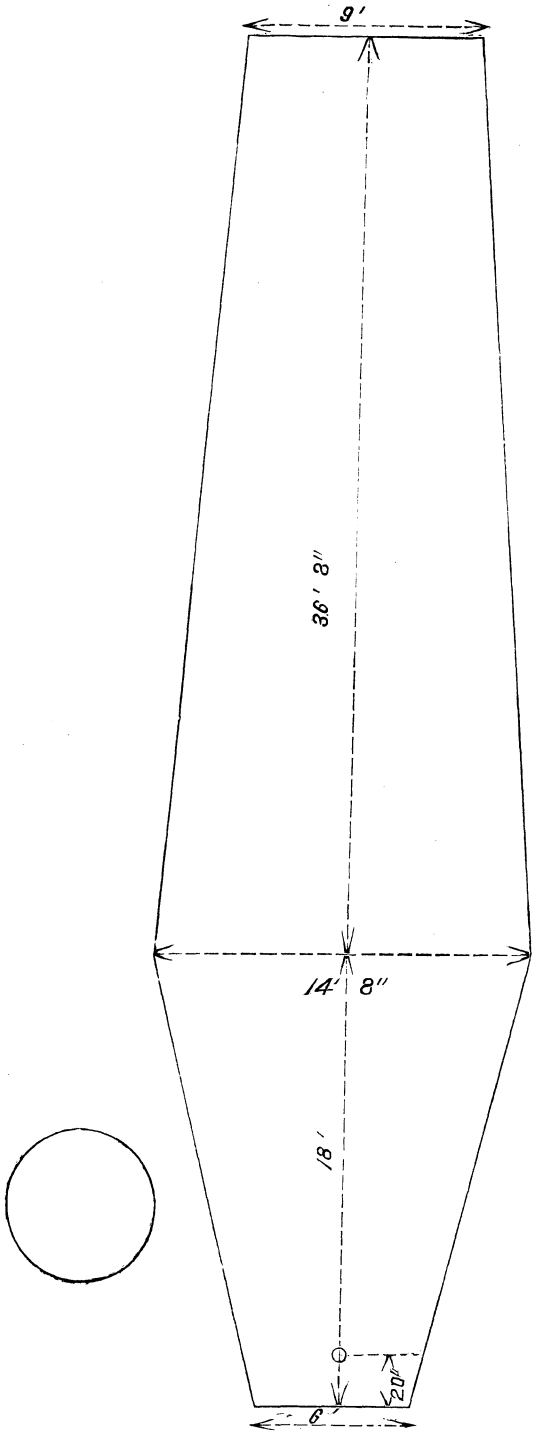


FIG. 38.

1. Spathic iron-ore.
2. Two cylinders.
3. Six tuyeres.
4. 601 Vienna centne
5. 150 pounds coke.
6. 84 per cent.

24. DIMENSIONS OF BLAST-FURNACES.—From data obtained at the exhibition, a writer in *Engineering* gives a very interesting tabular exhibit of the sizes and yield of some of the principal blast-furnaces in Europe.

*Principal dimensions of blast-furnaces in various parts of Europe.**

Description of furnace.	Number of tuyeres.	Height of furnace.	Diameter between. Tuyeres.	Boshes.	Top.	Capacity of furnace.	Yield per week.	Remarks.
Year of erection.		*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Cubic meters.*	*Tons.*	
Gleiwitz, 1854, coke-furnace.	3	15.58	.94	4.7	1.88	117.58	56.25	Open breast.
Gleiwitz, 1872, coke-furnace.	8	13.7	2.56	5.34	4	220.7	250	Closed hearth and top.
Königshütte, 1855, coke-furnace.	3	14.4	1.07	4.7	2.2	138.1	....	
Königshütte, 1865, coke-furnace.	7	14.8	2.5	4.7	3.14	204	....	Open hearth.
Königshütte, 1872, coke-furnace.	8	13.5	2.67	5.65	3.77	231.6	....	Closed hearth.
Creusot, coke-furnace	3	16.8	1.4	5	3	158.7	175	
Heinrichshütte, 1861, coke-furnace.	3	15	1.1	4.1	2.51	....	....	
Bessège, coke-furnace	3	14.1	1	3.96	2	....	112	
Wittkowitz, Moravia, coke-furnace.	7	18.72	2.24	5.44	3.2 / 4.8	....	....	
Prävali, Carinthia, 1872 ..	6	16.96	1.93	4.68	2.88	....	240	
Gleiwitz, charcoal, 1799 ..	......	11.18	.90	3.45	.96	40.31	13.7	Open hearth.
Gleiwitz, charcoal, 1829 ..	2	13.14	.63	3.14	1.36	48.14	25	Do.
Königshütte, charcoal, 1828.	2	12.11	.76	3.22	1.25	46.9	....	Do.
Bogshau, Hungary, charcoal.	4	13.3	1	2.85	2.02	56.5	100	
St. Gotraud, Carinthia, 1872.	3	11.2	1.16	2.56	1.11	....	46	Charcoal-furnace.
Waldenstein, Carinthia, 1872.	3	9.98	.85	2.56	.95	....	39	Do.
Combiers, charcoal, France.	2	8.79	.63	2.05	.62	....	17.5	Open hearth.
Friedau, charcoal, Styria.	......	13.27	1.89	2.26	.79	....	161	
Trummelsberg, Sweden ..	2	13.06	1.36	2.82	1.78	....	67.5	Charcoal-furnace.
Björnhittan, Sweden	2	12.76	1.17	2.67	1.45	....	31	Do.
Finnbo, Sweden	2	11.87	.94	2.37	1.39	....	24	Do.
Straczena, Hungary	......	9.28	.72	2.56	.85	....	....	Charcoal.

* Engineering, August 8, 1873, from the Vienna Exhibition.

25. FORMS ASSUMED BY FURNACES AFTER LONG WORKING.—In connection with this table of the principal dimensions of blast-furnaces, it is very instructive to compare the dimensions which furnaces assume after working for a long time. Engineering justly observes:

"This table gives good evidence that no general rules have, up to the present time, been deduced for the best form of blast-furnaces under certain conditions, as not even those furnaces which are in close vicinity to each other, and which are worked under similar conditions, have been built with corresponding dimensions.

"This fact will be understood easily enough when we say that only the original designs for the construction of a blast-furnace to be erected at a certain place happen to be brought to the knowledge of metallurgical engineers; but never, or very seldom only, are the results and experience gained in working this furnace brought before the public. This want of general rules becomes the more striking when we find that na-

ture itself has made the best engineer and draughtsman in this case, and that we only want to keep our eyes open to its teachings. Ambition and selfishness alone can have kept us so long from acknowledging these facts.

"It is clear that the best form of blast-furnaces will be that which, all other circumstances being equal, will work with the greatest economy of fuel and with the least deterioration of the furnace-lining. Now, instead of engaging ourselves with extended speculation about the mode of finding out the best form of furnaces, it would prove to be much wiser to look at the inside of such furnaces after they have worked effectively for some time. It is by no means a rare fact that blast-furnaces give the best working results a very short time before they are obliged to be put out of use on account of the general wear and tear of the lining.

"In all such cases the furnace itself, at the end of a campaign, will give valuable hints as to the form best adapted for the particular circumstances. But instead of learning, by close inspection, the wants of nature, in most cases we rebuild the furnace according to the original type, quite irrespective of the conclusions which may be drawn from the excessive deterioration of some parts of the interior.

"It is more than probable that the comparison of a series of such *self-formed* sections of blast-furnaces at the end of their campaigns will afford us means of deducing certain formulæ for the determination of the most effective form of coke or charcoal blast-furnaces, with due reference to the different circumstances under which they may work. But to arrive at such a desirable result, it is necessary before all that the different iron-masters and metallurgical engineers should aid the undertaking, by publishing the results obtained with furnaces of certain construction, and at the end of each campaign give a complete section showing the wear and tear of the lining. We believe it to be of the highest interest to all connected with the iron-trade that such knowledge should be largely diffused among the iron-works proprietors and metallurgical engineers."

Accordingly, *Engineering* presents sections obtained from drawings at Vienna of a charcoal blast-furnace, exhibiting in a striking manner the modification of the form of the interior after a campaign of five years' duration. These drawings are here reproduced. They represent one of a set of three furnaces at Mariazell, in Styria, working calcined spathic ores containing 42 per cent. of iron. It was lined with brick, and the crucible was built of sandstone. The broken lines in the vertical and horizontal sections show the ultimate shape assumed.

The furnace was working well when stopped on account only of the falling of part of the brick lining.

There is a striking similarity between these sections, the result of wear, and the form considered in some parts of Styria as the best for smelting spathic ores. Take, for example, a section of a charcoal blast-

Vertical sections of Mariazell furnace.

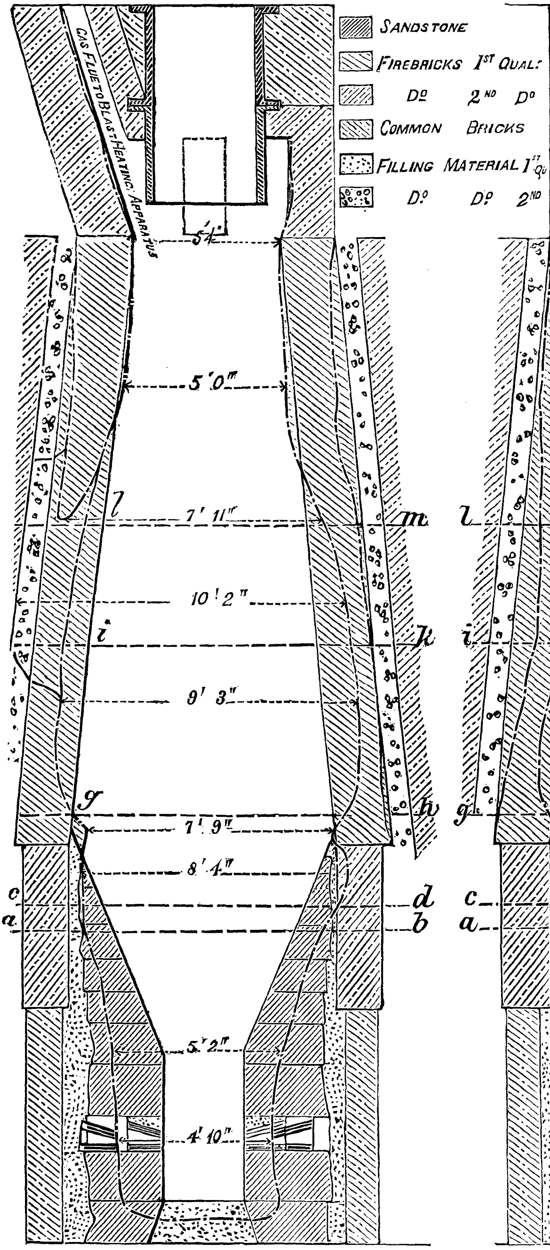


Fig. 39.

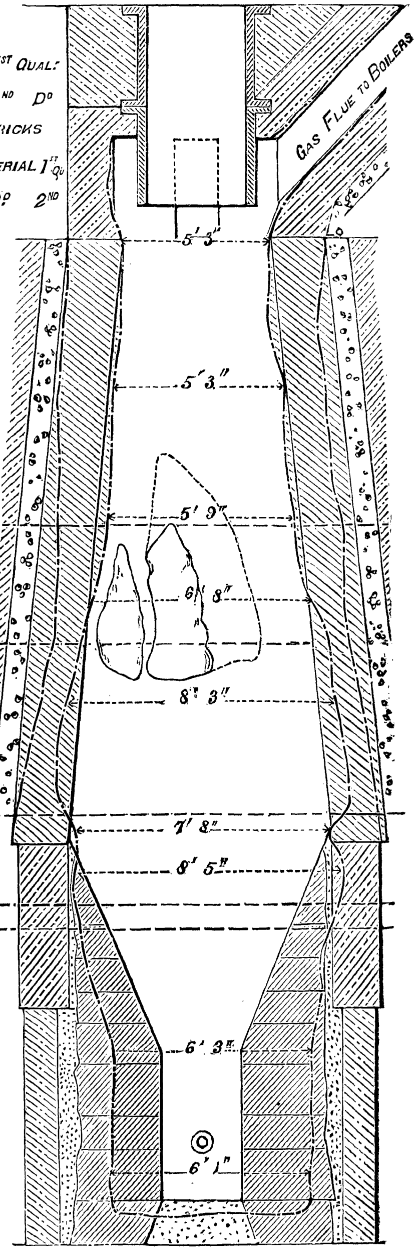


Fig. 40.

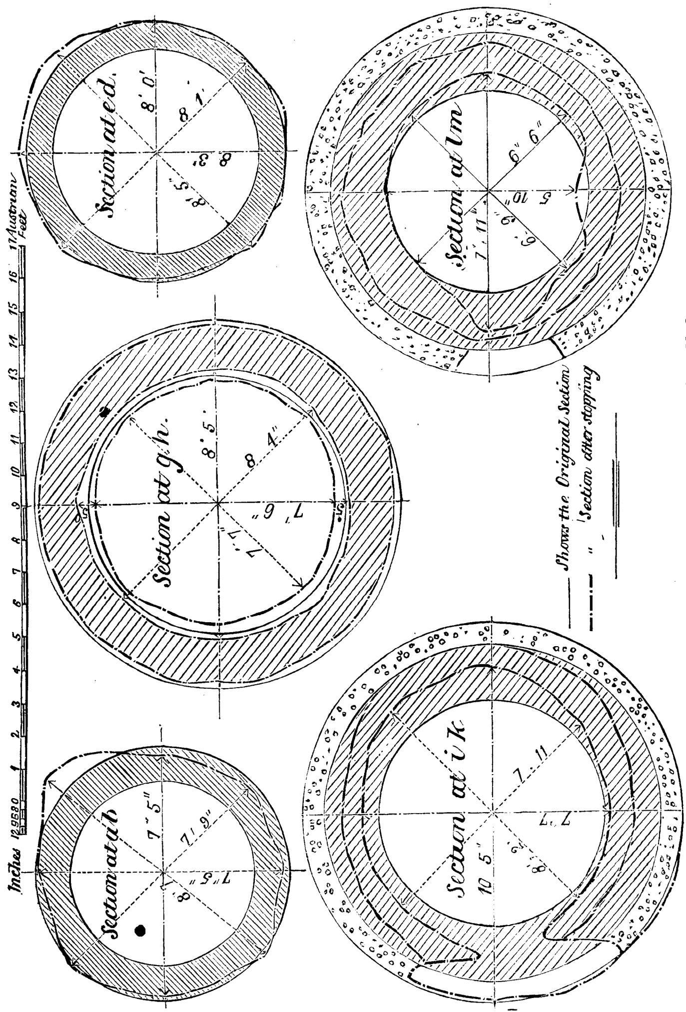


FIG. 41.—Horizontal sections of the Mariazell furnace.

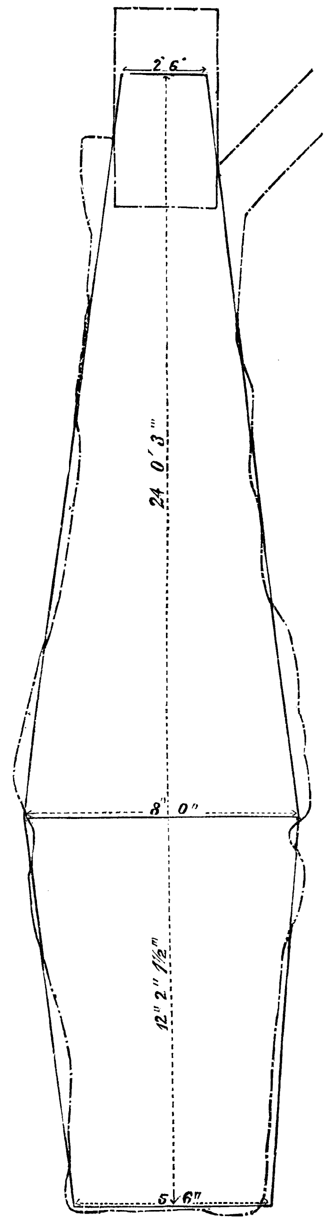


FIG. 42.—Vertical section of Styrian furnace.

furnace at Hieftau, near Eisenerz. It is nearly the same as the ultimate section of the Mariazell furnace.

In further illustration and confirmation of this tendency to assume a form corresponding closely to the shape and proportions believed to be the best in Styria, sections of another of the three Mariazell charcoal-furnaces are shown. These are contributed by J. Stummer-Traunfels, of Vienna, to *Engineering*, in corroboration of the views expressed, and are also very instructive. This furnace was also working in a satisfactory manner up to the time of the stoppage of the blast for the purpose of putting in a new lining. It had been in blast continuously for three years, and produced good iron with economy of fuel.

RESCHITZA STATE RAILWAY.

26. This company makes one of the most complete of the exhibitions of iron and steel, including the fuel used and models of the mines and apparatus for extraction of the ore. We here find a complete section of a bed of coal, showing the roof and floor, with a clay parting in the midst of the bed. This specimen is 14 feet 4 inches long, and stands about 6 feet high, the seam being inclined to the horizon. Here, also, is the largest Bessemer-steel ingot in the exhibition, 7 feet 1 inch long, and 33 inches in diameter, weighing 8,925 kilograms. There are, besides, a series of steel ingots, test-objects, showing the character of the fracture; a series of sections of rails with hard crystalline heads, and fibrous bottom, some with steel head and iron base. A series of sections of shape iron of various forms is shown to illustrate their internal structure, one being polished, and the other etched in acid, bringing out in this way the folding of the layers in the bars or the "fibrous" structure. A large tire for railway driving-wheels, 8 feet 9½ inches in diameter, attracts attention on account not only of its size, but its lightness and perfection of form.

In a fish-plate joint for rails a method of preventing the nuts from turning is shown. A small square plate of steel or iron, about one-eighth of an inch thick, is placed under the nut, and one side is raised up by a stroke of a chisel applied under the edge.

27. FERRO-MANGANESE.—A notice of the splendid exhibition in the Reschitza pavilion would be incomplete without more than a passing reference to the samples of ferro-manganese, or mangan iron, of three grades, containing from 25 per cent. to 35 per cent. of manganese. This alloy is very important in the manufacture of steel, and with the growth of the industry of steel in all parts of the world it assumes a constantly-increasing importance. The home-production of ferro-manganese is greatly needed in the United States, where it certainly might be made with our manganiferous ores and abundant fuel at a moderate cost. The process of manufacture, it will presently be shown, is very simple, attention however, being requisite to some important points, which might be overlooked and prevent success. At present the foreign metal is thrown into

Vertical sections of blast-furnace at Mariazell, Styria.

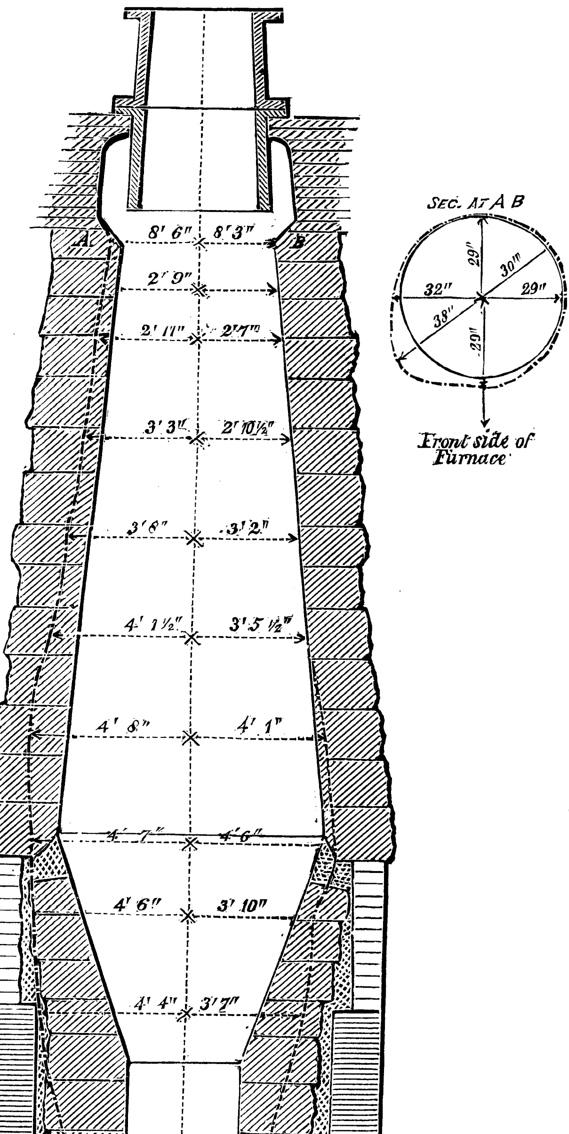


FIG. 43.

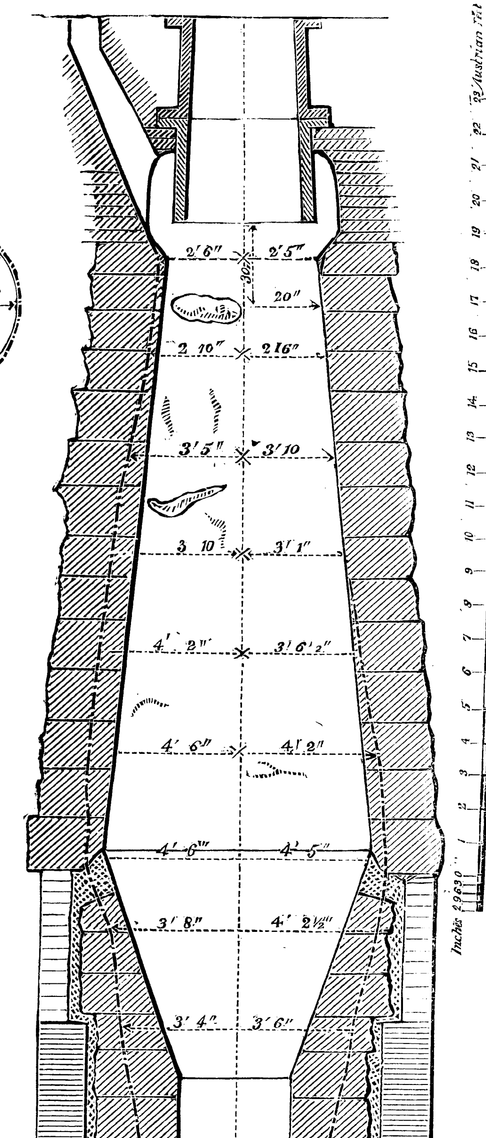


FIG. 44.

the market at constantly decreasing prices. This, and in general the comparatively small quantity required by our steel-establishments separately, appear to have discouraged the investment of capital in a special undertaking for the manufacture of ferro-manganese upon a large scale for the supply of the home demand.

28. At Reschitza, and probably at Laibach also, (the *Krainische Industrie-Gesellschaft,*) ferro-manganese is made in a blast-furnace, with charcoal as fuel and limestone as the flux. The ore is a ferruginous mixture, containing about 37 per cent. of sesquioxide of manganese. It is siliceous, and somewhat resembles in appearance the hard manganese-ore from Red Island, in the Bay of San Francisco, California. It contains about 29 per cent. of silica and some alumina, as shown by the subjoined analysis:

Analysis of ore used at Reschitza for ferro-manganese.

Silica	$Si\ O_3$	28.613
Alumina	$Al_2\ O_3$	8.073
Iron { Protoxide	$Fe\ O$	0.367
Iron { Sesquioxide	$F_2\ O_3$	19.031
Sesquioxide of manganese	$Mn_2\ O_3$	37.224
Lime	$Ca\ O$	2.430
Magnesia	$Mg\ O$	0.261
Water	$H\ O$	3.361

This ore in the furnace requires a large amount of limestone to be added as flux. The larger the quantity of limestone used, or the more highly basic the charge is made, the larger is the percentage of manganese in the product. Thus, by using 15 per cent. of limestone and 85 per cent. of ore, the product contains about 25 per cent of manganese. Doubling the amount of limestone, about 5 per cent. additional of manganese is gained, giving, say, 30 per cent. of manganese; trebling the quantity of limestone, the metal containing 35 per cent. of manganese. Thus, to recapitulate results which have been obtained, we have:

15 limestone	}	=25 per cent. manganese.
85 manganese-ore	}	
100		
28.6 limestone	}	=29 per cent. manganese.
71.4 manganese-ore	}	
100		
42 limestone	}	= 35 per cent. manganese.
58 manganese-ore	}	
100		

In a trial with the ore of which the analysis is given, 43 per cent. of limestone was added, so that the oxygen ratio of the bases to that of

the acid was as 15.88 to 10.68 = 1.48 to 1, or nearly as 1½ to 1. This for charcoal is a highly basic charge, but it is a most important condition in the manufacture of mangan iron.

To prevent the slagging-up of the furnace, it is necessary to have a high pressure of blast, much greater than is generally used in charcoal-furnaces, and as high as 90 to 100 millimeters of quicksilver. The blast, moreover, must be highly heated. In this instance it was carried to 250° Celsius = 482° Fahrenheit, the highest point attainable with the heating-apparatus of the Reschitza works at that time. With a higher temperature of blast and still more limestone, an alloy containing at least 50 per cent. of manganese could be produced. The furnace must be kept very hot, and the limestone always in excess.

The quantity of materials used and the costs of production can only be stated approximately. At Reschitza it was approximately as follows:

	Fl.	kr.
1,400 kilograms of ore	2	94
5 hectoliters charcoal	2	00
600 kilograms limestone		21
Labor, &c	1	00
Total in Austrian florins	6	15

The product being 50 kilograms of ferro-manganese, containing 35 per cent. of manganese. This sum is equivalent to, say, $3.10 for 100 pounds of ferro-manganese, being at this rate over $60 per ton.

Mixtures of iron and Bessemer steel.—There were some very interesting specimens illustrative of the effects produced upon soft gray pig-iron by adding Bessemer steel in increasing quantities. The specimens present a regular gradation in fracture from soft gray pig to hard white metal. Some large rolls for rolling iron were shown to which 12 per cent. of Bessemer steel had been added.

29. The *Krainische Industrie-Gesellschaft* of Laibach, Tyrol, exhibit an interesting series of specimens of spiegel iron and ferro-manganese, ranging from 8 to 35 per cent. of manganese. The alloy containing the high percentage of manganese is in blocks 9 inches thick, and breaks with a finely-bladed or columnar fracture, not exhibiting brilliant crystalline plates, but rather a fibrous structure. The ores are also shown, together with manganese and bauxite.

30. Rositzer Mining Company.—The *Rositzer Bergbau-Gesellschaft* make a very attractive installation illustrating their works and products. The whole does not occupy more than ten feet square at the base, but is in the form of a pyramid, rising about ten feet high, and formed of sections of rolled girders of different sizes, the largest at the base, and upon them samples of the pig-iron and of steel proof-ingots broken asunder, of bars and shafts broken across, and sections of rails and angle-iron. The ores (slags, fluxes, &c.) are also shown in an attractive

way. We also find castings, hoop and rod iron, model of workmen's houses, model of the machinery at the shaft; the hoisting-gear; a large cage, for two wagons side by side, fitted with a hood, eccentric safety-clutches, and a spiral spring.

The fire-brick used are also shown. Some of them are of great size, a yard or more in length and 9 inches thick, remarkable for their sharpness and excellence. Specimens of coal-fossils, photographs, and blocks of coal on the top of the pyramid, complete this compact and well-made exhibit.

31. JUDENBURGER IRON-WORKS.—The joint-stock company "Judenburger Eisenwerke," of Vienna, exhibited a number of boiler-plates of large size, a plan of the works at Judenburg, and a graphic chart of production and prices for the last eight years. The dimensions of some of the plates were—

Locomotive frame-plate, 8,015 × 765 × 9 millimeters, weighing 426 kilograms. Annual production, 1,600 to 2,000 pieces.

Tender frame-plate, 5,070 × 770 × 9 millimeters, weighing 264 kilograms. Annual production, 1,600 to 2,000 pieces.

Boiler-plate, 2,180 × 1,505 × 15 millimeters, weighing 393 kilograms. Annual production, 3,000 to 3,500 pieces.

Plate, 2,000 × 290 × 28 millimeters, weighing 126 kilograms.

Plate, 2,709 × 1,500 × 2 millimeters, weighing 71.5 kilograms. Annual production, 7,000 to 8,000 pieces.

Plate, 12,008 × 1,290 × 9.35 millimeters, weighing 1,071.23 kilograms.

Plate, 4,346 × 1,948 × 8.80 millimeters, weighing 546.10 kilograms.

Plate, 3,265 × 1,580 × 0.616 millimeters, weighing 24.5 kilograms.

Plate, 2,249 × 1,602 × 0.244 millimeters, weighing 6.47 kilograms.

Plate, 2,344 × 1,356 × 0.183 millimeters, weighing 4.5 kilograms.

The principal market for these plates is in Vienna, for the manufacture of locomotive-boilers, for steamboat-boilers, on the Danube, and at Prague, Brünn, and Pesth. Plate was supplied last year for over 400 locomotive-boilers. The following is a tabular statement of the production and price per zoll-centner for the last eight years:

Year.	Boiler-plate in zoll-centners.	Average price.	Total value.
		Fl. kr.	*Fl. kr.*
1864	22, 232. 03	8 79. 4	195, 525 78
1865	25, 075. 69	7 94. 7	199, 290 31
1866	48, 275. 24	7 10. 3	342, 923 80
1867	70, 922. 63	7 25. 6	515, 161 00
1868	90, 603. 42	8 31. 2	753, 098 53
1869	90, 451. 94	8 97. 3	811, 646 29
1870	103, 057. 11	9 04. 5	932, 144 73
1871	116, 465. 91	9 21. 6	1, 073, 311 20
1872	125, 321. 81	10 34. 8	1, 296, 777 16

The property of the Judenburger Company consists of puddling and rolling mills at Judenburg; coal-mines at Zeltweg, Styria; iron-

mine and blast-furnace at Olsa, Carinthia; rolling-mills in Hetzendorf, Styria.

At the rolling-mills of Judenburg there are 3 turbine wheels of 20 horse-power, one of 90 horse-power, and a water-wheel of 100 effective horse-power for a line of plate-rolls; three trip-hammers, one of which has a falling-weight of 24 and the other two of 20 centners; a large steam-engine of 200 horse-power for a line of plate-rolls.

There are, in addition, one large steam-hammer, with a falling-weight equal to 300 centners through one inch, and a five-foot stroke; 2 large steam-shears, with seven feet cutting-length, to cut 18 lines thick, cold; 10 puddling-furnaces; 2 Siemens heating-ovens; 10 heating-ovens of other construction; and a variety of other accessories to the manufacture.

This is the largest establishment for the manufacture of boiler-plate in Austria. The first Siemens welding-furnace was set up in 1869. The product of one furnace in twelve hours is usually over 3,000 kilograms, and sometimes rises to 5,000 kilograms. Over 300 workmen are employed. The pig-iron is obtained partly from the company's furnace at Olsa and partly from the blast-furnace at Treibach, from Vordernberg, and from Eisenerz. The coal comes chiefly from the company's mines at Zeltweg.

The works at Hetzendorf are intended chiefly for the manufacture of long sheets of plate-iron and plate of superior quality. The power is derived from a turbine wheel of 120 horse-power for a set of universal rolls; one turbine, of 60 horse-power, for a set of bloom-rolls; one turbine, of 20 horse-power, for the accessory work. There is one steam-hammer with a falling-weight of 100 centners, 6 feet stroke; one of 60 centners, 5 feet stroke; two Siemens welding-furnaces; seven puddling-furnaces; four heating-ovens for plate; and the corresponding shears and accessory machinery.

32. ROTARY PUDDLER.—A model of a rotary puddling-furnace plant, with regenerative furnaces, according to Dr. Siemens's plan, is shown by Joh. Willroider, of Villach, in the Carinthia building. The gearing is applied below; it is sustained upon plane-faced wheels. The opening at the back is closed by a square sliding door, and the puddled ball is to be withdrawn through this opening and to drop through a chute below into a car in the pit under the rotating vessel. The flame enters and returns on opposite sides of a vertical wall, while in the Sellers puddler in the United States section the division is horizontal.

33. EHRENWERTH'S PUDDLER.—We have in the same building a model of a new form of rotary puddler, designed by Joseph v. Ehrenwerth, of the K. K. Bergakademie zu Pribram, Bohemia. The two vertical sections annexed will serve to show its construction and method of working.

The horizontal pan-shaped hearth A (Figs. 45 and 46) is supported upon a pivot, W, to which motion is imparted by bevel-gearing. An

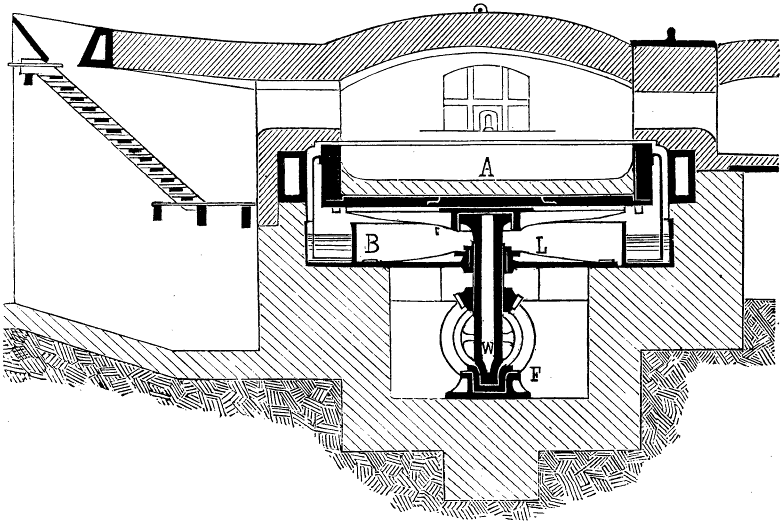


FIG. 45.—Longitudinal section.

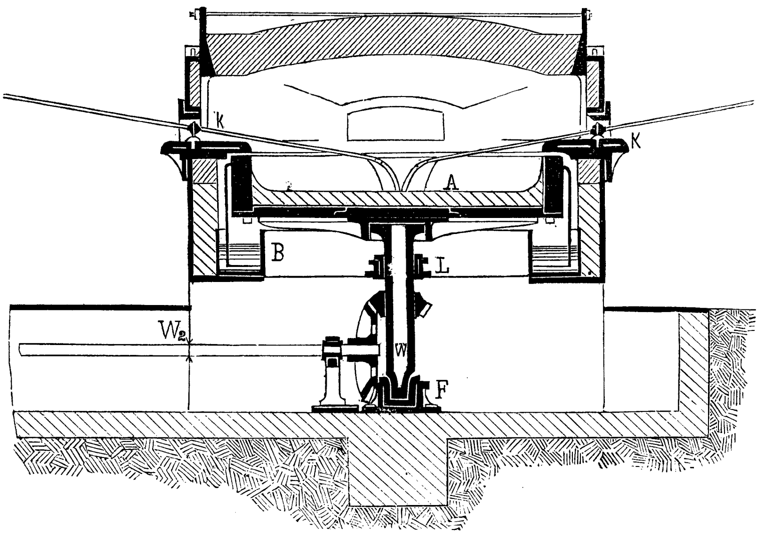


FIG. 46.—Transverse section.

EHRENWERTH'S ROTARY PUDDLING-FURNACE.

annular trough filled with water below the rim of the hearth serves to form an air-tight joint, keeping the flame from the gearing and supports below. The rabble is fixed at one side. The cost is stated at about $2,000. Its value for the intended object remains to be shown by use.

The annexed additional description is translated from the inventor's circular stating the advantages of this form of puddler.

The puddling-furnace with rotating hearth differs from the ordinary puddling-furnace only in the fact that the hearth, which is fastened to a vertical shaft, can be set in rotation.

Any method of heating desired can be used. The model represents a furnace with gas-heating apparatus with Siemens regenerators, and the drawing such a furnace with inclined grate.

In the drawing, F is the foot-journal and L the neck-journal, W the vertical shaft, A the hearth, which is fastened to the rosette *r*.

The hearth consists of the bed-plate and the hearth-wall. Both are formed of many pieces of cast iron, as indicated in the model. The hearth-wall can be coated on the inside with any suitable refractory material.

In order to exclude the air from the interior of the furnace, a cylinder of plate is fastened to the bottom of the hearth, or to the wall of the same, which dips in water contained in the annular basin B, having constant inflow and exit. The annular basin is attached, air-tight, to the furnace-wall.

In order to cool the bottom, jets, with roses attached, are introduced, which sprinkle water against it. The cooling of the side-walls is effected in different ways according as the cylinder of plate, necessary for the exclusion of the air, is attached to the bottom or to the rim of the hearth. In the first case the parts of the wall are hollow, as shown in the model, and the cooling-water is conducted through pipes *r* under pressure into the hollows. The escaping water falls over the lower edge into the basin, (model.) In the latter case, which is to be more recommended, the cooling-water is conducted against the hearth-wall through jets fixed in a circle, and then drops into the basin. In this case the hearth-walls may be made solid.

The motion of the hearth is imparted to it by means of toothed gearing, from the driving-shaft W_2, which is set in motion by means of a belt from a main shaft. For large works it is advantageous to have one subterranean main-shaft common to all the furnaces.

The operation of the hearth is as follows: After the charging is finished the hearth is set in rotation. If it is intended to stir the bath after complete melting, then rabbles provided with broad blades placed obliquely are introduced through the balls *k* inserted in the furnace-doors, and the puddling is performed either by hand or machine, from the edge of the hearth toward the center. If the rabbles are placed obliquely from opposite sides, and one worked toward the center and the other toward the outside, the best possible puddling is obtained by means of this double motion of the hearth and rabbles.

The blooming is done by hand as ordinarily in the furnace with fixed hearth, and during this time the hearth is intermittently in motion, in order, after completion of a bloom, to bring another mass of iron again before the door.

After the blooming the hearth is again set in rotation, in order to expose the blooms to as uniform a heat as possible. The blooms are afterward taken out and drawn in the usual way.

The excess of slag, formed by each new charge, is taken out at the end of the process by means of a ladle. (It can, however, be allowed to flow off, during the working, over two places in the hearth-wall, which are lower than the rest.)

The charge for a furnace with two working-doors is 15 to 20 centners. To work such a furnace, when the puddling is not done by machinery, four men are generally necessary, two or three workmen, and a fireman. The power required is about $\frac{1}{2}$ to $\frac{3}{4}$ horse-power. The most advantageous number of revolutions during the puddling is about 20 to 24 per minute. The advantages which the puddling-furnace with rotating hearth offers are based upon the facts that the working is done either partially or wholly by machinery, and in consequence of the rotation of the hearth all parts of the iron pass through the same phases of heat, and are also entirely and uniformly heated. The advantages over the ordinary puddling-furnace are especially the following:

1. Cheaper production, in consequence of the saving of fuel and hand-labor.

2. Increased production with an equal outlay of capital.

3. Independence of the ordinary puddler. Even with the fixed rabble the work is accomplished.

4. Uniformity of product, in consequence of thorough puddling and uniform heating.

5. Easy regulation and control of the running.

6. Saving in health and comfort to puddlers.

This rotating-hearth puddler is claimed also to be especially well suited to steel-puddling, and to offer greater advantages to this than for iron-puddling.

34. HYDRAULIC FORGING.—A suit of parts of railway running-gear and of parts of locomotives is shown by Mr. Haswell, of the Imperial State Railway Works, near the depot of the Southern Railroad, Vienna. These objects are extremely interesting, not only to manufacturers of locomotives, car-wheels, &c., but to industry in general, as illustrations of what may be accomplished by Haswell's method of forging iron or steel by direct pressure, slowly applied to the metal while hot. The description of this method forms a separate chapter of this report.

35. WIRE-ROPE TRACES.—The St. Egydy and Kindberger Iron and Steel Industry Company, formerly Anton Fischer, of Vienna, exhibited a large number of wire-rope traces adapted to farming purposes, wagons, and wherever leather traces or chains are used for draught.

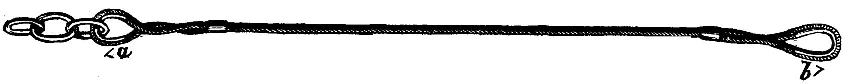
These traces have the advantages of great strength, lightness, pliability, and durability, and, besides, are cheap, as will be seen from the annexed table of sizes and prices. The lengths are stated in Austrian feet, and the price in florins and kreutzer.

Sizes and prices of iron traces.

[Length in Austrian feet.]

Diameter in lines.	3½ to 4.	Over 4 to 4½.	Over 4½ to 5.	Over 5 to 5½.	Over 5½ to 6.	Over 6 to 6½.	Over 6½ to 7.	Over 7 to 7½.	Over 7½ to 8.
	Fl. kr.	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*	*Fl. kr.*
2⅛	1 90	1 95	2 00	2 05	2 10	2 15	2 20	2 25	2 25
3	2 05	2 10	2 15	2 20	2 25	2 30	2 35	2 40	2 55
3½	2 25	2 30	2 35	2 45	2 50	2 60	2 65	2 75	2 90

The form of these traces and the arrangement of loops and links at the end are shown in the figure.



Galvanized iron-wire traces.

The loops at the ends are fitted with metal guards to receive the wear. The rings are made of wrought iron. The lengths stated are from *a* to *b*. The rings add from four and a half to six inches. The whole surface is galvanized or zinked to prevent rusting.

* The Austrian foot = 1.0371 feet; Austrian florin = 50 cents, approximately; and the kreutzer half a cent.

CHAPTER II.

GERMAN EMPIRE.

EXTENT AND ARRANGEMENT OF THE IRON AND STEEL DISPLAY; EXTENT OF THE PRODUCTION; CHIEF LOCALITIES; RAPID GROWTH OF THE INDUSTRY; DEVELOPMENT OF STEEL-MANUFACTURE; CAST STEEL; GRAPHIC ILLUSTRATIONS OF PRODUCTION; IMPORTS AND EXPORTS; NUMBER OF EXHIBITORS; BORSIG'S DISPLAY OF LARGE BOILER-PLATE; DILLINGER SHEET-IRON; STYRUM COMPANY; IRON SHOES FOR RAILWAY-BRAKES; KÖNIGS AND LAURAHÜTTE; IRON GIRDERS AND COLUMNS, BURBACH WORKS AND PHŒNIX IRON-WORKS; IRON RAILWAY-TIES, BURBACH, SCHALTENBRAND, AND OTHERS; KRUPP'S DISPLAY; DESCRIPTION OF THE WORKS AND PRODUCTS SHOWN; THE FIFTY-TWO-TON INGOT OF CRUCIBLE STEEL; ARTILLERY MATERIAL OF CRUCIBLE STEEL; BUTTGENBACH'S BLAST-FURNACE; OSNABRÜCK IRON AND STEEL WORKS; GLEINITZ FURNACE; DIMENSIONS OF FURNACES AT DIFFERENT PERIODS.

36. The exhibition of the iron and steel industry of the German Empire is magnificent and highly instructive. It is arranged with the other mining and metallurgical products chiefly in a special building, between the Industry Palace and the Machinery Hall, while Krupp's unrivaled display occupies another structure alongside.

37. The total values of the ores raised in the empire, exclusive of Elsace and Lothringen, in the year 1870, amounted to 7,116,828 thalers, as shown by the statistics presented at the exhibition, from which the annexed statement of the number of establishments, men employed, and the aggregate production in the year 1871, is compiled:

	Number of works.	Number of men.	Production.	Value.
			Cwt.	*Thaler.*
Iron-ores	1, 258	24, 973	58, 550, 539	7, 116, 828
Cast iron	631	39, 525	29, 942, 264	49, 251, 650
Wrought and rolled iron	354	43, 849	17, 437, 766	57, 490, 284
Steel	216	12, 892	3, 399, 027	22, 747, 626

38. The chief seats of the German iron-industry are the Silesian provinces, Westphalia, and the Rhenish provinces of the kingdom of Prussia. The great increase of the development of this industry of late is shown by the fact that the production of pig-iron, which in the year 1825 did not exceed 1,004,162 centners, amounted to nearly 30,000,000 centners in the year 1871. According to the returns of the united German customs, there were in 1861 469 cupola-furnaces, (Prussia, 310;) 207 iron-wire works, (Prussia, 166, of which 146 were in the province of Westphalia;) 296 steel-works, including steel-rolling and steel-wire works, (Prussia, 275;) 982 iron and tin ware works, including scythe, chain, anchor, nail, and other works, with 13,336 workmen, (Prussia, 794; Bavaria, 66; Würtemberg, 42;) 548 steel-ware and edge-tool works, with 3,081 workmen, (Prussia, 460, of which 427 were in the Rhine provinces;) 421 iron-railing works, heating and cooking apparatus works, with 12,077 workmen, (Prussia, 242; Sax-

ony, 43;) 50 manufactories of arms, with 4,188 workmen, (Prussia, 35;) 65 nail-works, with 3,729 workmen, (Prussia, 34; Bavaria, 30.)

39. In the year 1871, Prussia alone produced 5,689,944 centners of cast-iron ware in 492 works, with 24,600 workmen; 1,840,159 centners of sheet-iron in 59 works, with 4,536 workmen; 157,443 centners of tin-plate in 6 establishments, with 826 workmen; 1,091,042 centners of iron wire in 43 works, with 3,185 workmen; 3,664,064 centners of steel in 78 establishments, with 15,290 workmen, of which 2,963,313 were cast steel in 34 works, with 13,656 workmen.

40. The development of the Prussian steel-industry is extremely interesting. In the year 1825, the production did not exceed 62,065 centners. In 1832, a small quantity, 94 centners, of cast steel was made, but the quantity of steel increased rapidly to 723,297 centners in 1862, including 274,662 centners of cast steel. Upon the general introduction of the Bessemer process in 1863, 579,508 centners of cast steel were made, while the total steel-product rose to 952,767 centners. The percentage of cast steel in the total manufacture amounted in the year 1832 to less than 6 per cent., in 1850 14 per cent., in 1855 to about 29 per cent., 1862, about 38 per cent., in 1863, nearly 60 per cent., and in 1871 to about 71 per cent.

Prussian ores.

	1873.	1872.	Increase.	Decrease.
	Tons.	*Tons.*	*Tons.*	*Tons.*
Bog iron-ore	25, 685	29, 012	....	3, 327
Brown hematite	1, 574, 657	1, 651, 550	....	86, 893
Spathic carbonate	742, 900	771, 465	....	28, 565
Clay ironstone	55, 396	26, 767	28, 629	....
Black band	223, 467	275, 420	....	51, 953
Hematite	698, 148	657, 181	40, 967	....
Magnetic iron-ore	10, 415	9, 277	1, 138	....
Limonite, (bohnerz)	223, 986	240, 692	....	16, 706
Specular iron-ore	353	....	353	....
Total	3, 555, 005	3, 671, 264	....	116, 359

41. The above table shows the nature of the ores and the quantity raised in Prussia, during the years 1872 and 1873, with the increase and decrease. The total product of iron-ores during the year 1874 is given at 2,090,133 metrical tons, valued at about £893,461, a diminution of no less than 1,464,872 tons in quantity, (£776,384 in value,) as compared with the production in 1873.

The following data show the production, estimated value, and number of hands employed in the different government iron-works in Prussia in 1874:

	Production in centners.		Value in thaler.		Workmen.	
	1874.	1873.	1874.	1873.	1874.	1873.
Iron-ores	1, 203, 324	2, 286, 315	187, 049	410, 152	531	818
Pig-iron	368, 276	324, 974	573, 213	760, 651	273	267
Iron castings	173, 086	226, 994	703, 330	1, 128, 745	796	987
Parts of machines	29, 528	41, 250	348, 935	420, 169	366	303
Steel articles	1, 174	890	19, 244	15, 789	16	17

42. The rapid increase in the production of iron and steel for the last forty years is well illustrated by a series of graphic charts on a large scale hung upon the walls of the entrance to the German building for mining industry. These charts show in colors the relative product of each year from 1837 to 1871 in millions of kilograms.

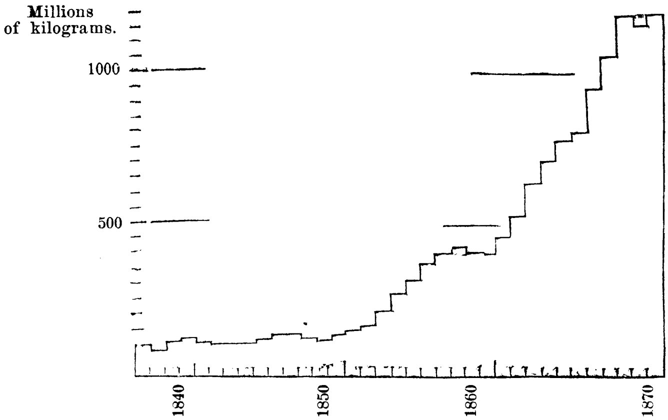


FIG. 47.—Production of pig-iron, Prussia, 1837 to 1871.

The chart for pig-iron shows a gradual increase through each decade, but the chart of steel-production shows a very rapid augmentation of product since 1860.

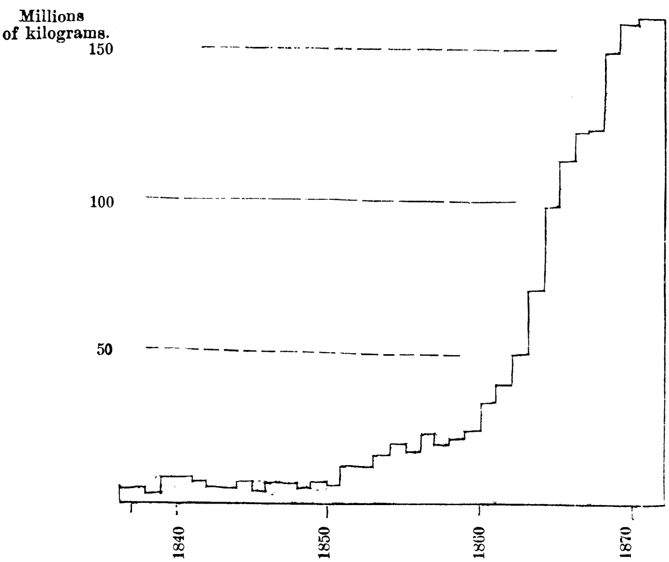


FIG. 48.—Production of steel, Prussia, 1837 to 1871.

Each of these diagrams shows a very considerable fluctuation of production from year to year, but, on the average, a constant increase, highly encouraging to the industry of iron.

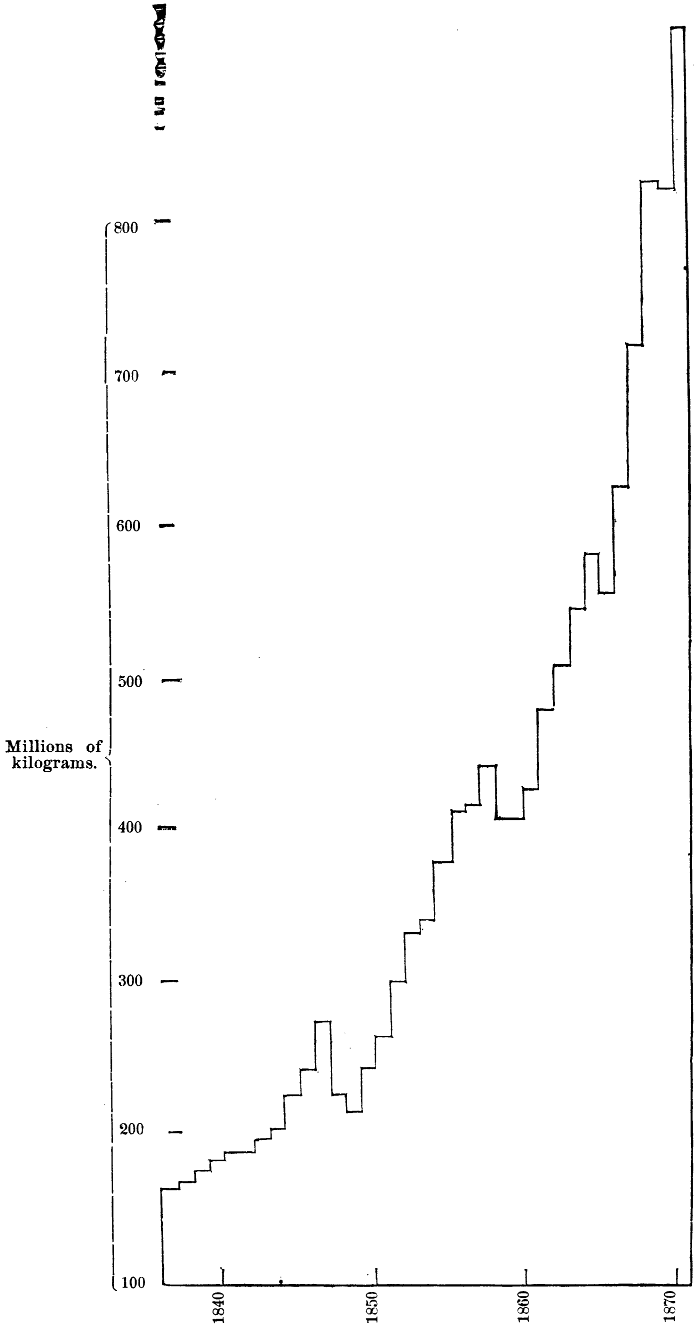


FIG. 49.—Production of bar-iron, Prussia, 1837 to 1871.

43. The German trade in iron and steel, and manufactures from them, is very considerable, as shown by the customs returns for the year 1871, giving, as below, the imports and the exports:

	Imported.	Exported.
	Cwt.	*Cwt.*
Pig-iron	11, 849, 410	4, 137, 844
Wrought iron	1, 418, 809	1, 212, 885
Railroad-iron	2, 017, 511	2, 553, 908
Steel	93, 731	161, 349
Iron and steel wire	36, 360	161, 127
Heavy wrought-iron and steel objects	765, 981	1, 225, 188
Wrought-iron pipe	138, 011	119, 432
Heavy castings	437, 505	496, 231
Sheet-iron and steel-plate	597, 840	323, 557
Tin-plate	70, 105	58, 289
Fine iron ware	12, 160	22, 558
Nails, needles, steel pens, &c	76, 134	22, 477
Total	5, 664, 747	6, 357, 001

44. The number of exhibitors in Group I alone is not less than one hundred and seventy-two, most of them being iron and steel works of considerable magnitude, but this number includes also exhibits of coal, copper, lead, zinc, &c. There are, besides, in the section of Group VII (Metal Industry) devoted to manufactures of iron and steel no less than two hundred and fifty exhibitors, but these include many manufactures not ordinarily classed with iron and steel products.

Only a few of the more prominent exhibits, in regard to which notes were made, can here be noticed.

45. A. BORSIG, UPPER SILESIA.—This firm, with large establishments in Silesia, and also near Berlin, makes a fine display of cast-steel ingots, sections of girders, piston-heads, boxes, and various parts of machinery. There are some large and well-forged cranks and connecting-rods, large boiler heads and plates, in cast steel, one weighing 480 kilograms; another 5,300 by 1,500 by 13 millimeters, weighing 950 kilograms. Among the large boiler-plates, (presumably of iron,) two may be cited for their great size and perfection. The first, 6,400 by 2,200 by 5 millimeters, weight 550 kilograms; the second, 8,000 by 2,100 by 13 millimeters, weighing 1,700 kilograms. Two sheets of locomotive-boiler plate, respectively, 7,400 by 1,010 by 30 millimeters, weight 967.5 kilograms, 7,500 by 1,170 by 40 millimeters, weight 2,730 kilograms, received the Progress Medal. The central portion of this fine display consists of a glass case containing the smaller objects surmounted by a stack of ore. There is a monumental pyramid of coal, with a bust of Borsig (?) at the top. Progress Medal.

These works were established in 1863. There are now (1873) 4 blast-furnaces, 40 puddling-ovens, 21 heating-ovens, 3 annealing-ovens, 3 steel melting-ovens, and 2 heating-ovens. They produced in 1872, with 1,542 workmen, 400,000 hundred-weight of pig-iron, 26,000 hundred-weight castings for the use of the works, 300,000 hundred-weight of rolled iron, 26,600 hundred-weight steel for the German market. Open-hearth steel by Martin's process is a specialty of these works.

46. Dillinger Company.—The Dillinger Stock Company makes a fine display of rolled plates, of large size and of all thicknesses, manufactured of superior charcoal-iron. These sheets of iron comprise reservoir-iron, bridge-sheets, locomotive-boiler plate, and ordinary sheet-iron and tin-plate. One sheet of reservoir-iron weighs 2,130 pounds, and measures 6,500 by 1,900 by 11 millimeters; a bridge-plate measures 150,000 by 1,000 by 9 millimeters, and weighs 2,100 pounds. A locomotive-plate 4,100 by 1,900 by 19 millimeters. Button-iron is shown in sheets 456 by 305 by 0·26 millimeters. Some of the sheet-iron is so thin that 38½ sheets are required to make a thickness equal to one millimeter. Buckled plates and corrugated iron are shown in great variety, and apparently of unusually good quality.

This establishment was founded in 1763. In 1872 the production was about 400,000 hundred-weight of sheet-iron, including the tinned and zinked iron. About 2,000 men are employed.

47. Styrum Company, Oberhausen.—The stock company at Styrum, in Oberhausen, Rhenish Prussia, send some very large rectangular and circular boiler-plates, with bar and angle iron of all forms. One boiler-plate measures 3,770 by 2,305 by 13 millimeters, and weighs 1,025 kilograms. The circular boiler-head is 2,550 millimeters in diameter and 15 millimeters thick, and weighs 625 kilograms.

These works were established in 1857. In 1872 the production, with 650 workmen, was about 300,000 hundred-weight. There are 40 puddling-ovens, 20 heating-ovens, and 11 rolls.

48. Iron shoes for railway-brakes.—The brothers Glockner, of Tschirndorf, near Halban, in Silesia, send a variety of forms and sizes of brake-irons for the use of railways. They have agents in England, Russia, Bavaria, Austria, and Hungary. This concern makes a specialty of steel castings, and produced in 1872 7,000 hundred-weight with 95 workmen and two cupola-furnaces.

49. United Königs and Laurahütte.—The furnaces and rolling-mills of this company were represented by a conspicuous stack of bar-iron, rails, rods, and sheet-iron tastefully arranged upon a pedestal surmounted with an iron crown, and bound around with a sheet-iron band, tied in a bow-knot. This was placed in the rotunda. The bars and rods were variously twisted and tied into knots to show their toughness and strength.

There are 7 blast-furnaces at Königshütte, and a rolling-mill, besides works for Bessemer steel. At Laurahütte there are eight furnaces, six of which produced 35,000 tons of pig-iron in 1872.

IRON-WIRE INDUSTRY IN WESTPHALIA.

50. The Westphalian Union Joint-Stock Company in Hamm, on the Lippe, (*Westfalische Union Actien-Gesellschaft für Bergbau, Eisen, und Draht-Industrie,*) is a recent incorporation representing several distinct establishments, which, as united, is claimed to be the largest undertak-

ing in the world for the manufacture of iron and steel wire. Over 2,800 men are employed, and the total annual production of manufactured ware, exclusive of pig-iron, is about 84,000,000 pounds, and is increasing.

Until recently this great industry was in the hands of a few private firms. The chief market for their production was in the cities of Iserlohn and Altena, and their vicinity, for the manufacture of needles. A number of small mountain-streams supplied the power for grinding and polishing the needles. But the rapid spread of the electric telegraph and the substitution of iron for copper wire in its construction completely changed the market and revolutionized the wire-industry of this region.

Another very considerable demand for iron and steel wire grew out of the use of wire-ropes in mining-operations and the greatly extended consumption of wire-nails. Wire-nails for many years were of small size, not much larger than carpet tacks or brads, but now they are made of almost all dimensions, up to one-quarter of a meter in length and three-quarters of a centimeter in diameter. They are largely used in building, are made by machinery, and are very cheap. They have driven wrought nails, excepting only horseshoe-nails, from the market.

Another important consumption of the wire made in the works of the Westphalia Union is in the manufacture of rivets, screws, springs, and of wire-cloth and lattice-work. It is largely used also for wire-cordage for ships' rigging, for teledynamic cables, and for suspension-bridges.

These are some of the many uses of wire cited by the company in the brochure which they print in German descriptive of their works and production. They draw attention to the fact that the quality of wire is not of so much importance in their estimation in the manufacture of nails and screws as in the manufacture of needles, rivets, and wire-rope, and sometimes, also, of telegraph-wire. These latter require considerable hardness and tensile strength in the wire. For the production of wire-rope, and also telegraph-wire, it is important that the wire be in as long pieces as possible. The company claims for its products a world-wide reputation, and gives a statement in some detail of their distribution and uses in several countries, from which the following is condensed.

51. The high reputation which the Westphalia wire-industry has obtained comes from the fact that the different works have made the manufacture of wire a specialty, and by long experience have been able to satisfy the demands of the needle-trade as regards quality.

The Westphalia wire-industry had also better opportunity for the selection of suitable raw material than other localities, and the works could produce blooms directly from the pig, which could be rolled into wire in a second manipulation without the manufacture of a costly intermediate product. The importance of these advantages over other localities, and the care exercised in the manufacture, enabled the West-

phalia wire-industry to overcome the competition of the English and French. Westphalia telegraph-wire is used in various submarine cables; stretches over the great Russian Empire; withstood competition with the English wire used by the English government in the East Indies, for which tests were required which other manufacturers considered unattainable. It is used by the Brazilian government; it was well known in the Parisian market before the French war, and obtained this market afterward, and is used by the Prussian and German government telegraphs. In the Franco-Prussian war of 1870-'71, the great demand for field-telegraph wire was supplied by the firm of Cosack & Co., now the Hamm division of the Union. It is not strange, therefore, that this wire-industry, which was previously in the hands of a few firms, drew the attention of capitalists, and a joint-stock company was formed, in order to secure more capital and a consolidation of interests against competition. Four of the most important works of the Westphalia wire-industry now united under this firm will be noticed in succession.

52. HAMM DIVISION, (formerly COSACK & CO.)—Annual production, about 28,000,000 pounds of rolled wares. The works are situated on and connected with three principal railways, with an area of about thirty acres. The manufactures consist of the following chief products: Bar-iron and rolled wire, drawn wire, especially telegraph-wire, wire for wire-ropes, &c.; wire-tacks, springs, boiler and bridge rivets, and carriage-axles. The plant of these works consists of 30 puddling-furnaces, including 2 "Schrott ovens," 9 heating-ovens with blast, 38 steam-boilers, 3 steam-hammers, 1 lift-hammer, and 6 lines of rolls, 2 of which are for bloom-iron, 2 for bar-iron, and 2 for rolled wire, besides the ordinary shears and saws. There are 14 driving-engines, besides the necessary accessory engines, giving altogether about 450 horse-power, with water-pumps, steam-pumps, &c. The rolled wire produced is for the most part further worked in 2 drawing-mills and a tack-shop. In a rivet-shop, boiler and bridge rivets are made in 7 machines; 6 hammers and 20 lathes and drills serve for the manufacture of axles. The establishment possesses 1 iron-foundery with 3 cupola-furnaces and 1 reverberatory furnace, 1 machine-shop, 1 apparatus for zinking fourteen wires at the same time, 1 factory for green vitriol, (sulphate of iron,) 1 factory for fire-brick, and 4 limekilns.

53. NACHRODT DIVISION, (formerly ED. SCHMIDT.)—This has an area of about 150 acres and railway connection with the "Bergisch-Märkisch" Railroad, with a solid bridge over the Linne. Annual production, about 24,000,000 pounds of finished goods. These works have the advantage of a very important water-power of the Linne at their disposal, and, indeed, the works are run by the following: 1 water-wheel of 100 horse-power, 1 water-wheel of 60 horse-power, 1 Köchlin turbine of 135 horse-power, 1 second turbine of 100 horse-power, 1 third turbine, for running the drawing-shop, of 10 horse-power, making a total of 405

horse-power. Such an available water-power represents a considerable capital in comparison with the cost of steam-engines and boilers, with expenses for repairs, and the consumption of coal. These works were, therefore, in a situation, being alongside the rolling-mill, which, by the waste heat, afforded enough steam for the finishing of the product, to take up some manufacture which required greater power than the heat from the gas-furnaces produced, as is the case with the manufacture of thin plate. Although the manufacture of rolled wire is the most important, these works also produce a considerable quantity of tin-plate as well as sheet-iron, button-plate, and brass-plate. The plant consists of 21 puddling-furnaces, 7 heating-ovens, 22 steam-boilers, 3 steam-hammers, 6 steam-engines, 3 bar and bloom rolls, 2 refined iron lines of rolls, 1 wire line of rolls, 4 pairs of plate-rolls for tinned plate, sheet-iron, and button-plate, and also 2 pairs of rolls for brass-plate. The manufacture of rivets, nuts, and screws is considerable, and during the last working year reached about two and one-third million pounds, which yielded a very good profit. The works possess a foundery, draw-shop, blacksmith-shop, repair-shop, and all the necessary accessories. There are also in process of building, 4 puddling-furnaces for utilizing fine wire and plate-waste, 1 bloom-roll, and 1 steam-hammer.

54. LIPPSTADT DIVISION, (formerly A. & TH. LINHOFF.)—Annual production, about 13,000,000 pounds of finished goods. The puddling and rolling mill at Lippstadt produces chiefly wire and wire fabrics, and also merchant iron. The works are connected with the Westphalia Railway, and possess about twenty-eight acres of territory in the immediate neighborhood of the station. The puddling and rolling mill contains 12 puddling-furnaces and 3 heating-ovens, each oven being provided with a boiler. The works have 3 sets of rolls and 1 bloom-roll, 1 bar-roll, and 1 quick roll for wire; 2 steam-hammers, and 2 small lift-hammers for the manufacture of beaten iron; finally, 1 drawing-mill, with 12 large-sized and 68 medium and fine sized rolls. The drawing-mill and tack-factory at Belecke, belonging to Messrs. Linhoff, have also been added to the property of the company. This has an area of about forty acres, besides water and steam power. The factory contains 46 wire-tack machines, 16 large-size rolls, 8 fine size, and 8 medium size in process of erection. All the shops possess the necessary repair-shops, with lathes, drills, planing machines, &c. The charcoal-furnace at Bericherhütte, in Fürstenthurm, Waldeck, also belongs to the Linhoff Works. This furnace has a daily production of about 40 centners of the best charcoal-iron, of unusual strength, which is especially suited for piano-wire and scraper-wire, but is employed mostly for hard castings, parts of rolling-machines, square and corrugated rolls, puddling-furnace canals, crucibles, &c. This furnace has the right of pre-emption for charcoal in the Fürstenthurm, Waldeck, and possesses 57 shares (out of 128) in a mining concession of 521,750 square "lachter" (fathoms) of a very valuable iron-ore. A railway now built is intended to bring the mine into communication with

the station Bredlar. This railway is conducted by the mine-owners, and was to begin operation in July, 1873.

55. WERDOHL DIVISION, (formerly FRIEDRICH THORNÉE.)—Annual production, about 19,000,000 pounds of manufactured products, such as rolled wire, drawn wire, and springs. To this division belong:

a. The puddling and rolling mill in Werdohl, with 14,000,000 pounds' production, situated immediately by the station, and connected by a side-track with the "Bergisch-Märkisch" Railway. These works have 16 puddling-furnaces, 3 heating-ovens, 16 steam-boilers, 2 bloom-hammers, 1 bloom-roll, 2 wire-rolls, and a repair-shop with roll-drawing apparatus.

b. The works in Uetterlingsen, (wire-drawing mill.)—These are situated on the Linne, a quarter of a mile from the station Werdohl, and have a water-privilege of about 250 horse-power and 1 steam-engine, driving 48 large-size, 22 medium-size, and 130 band and scraper rolls. There are also machines for drawing spring-wire. There are about 2,500,000 pounds of products.

c. The puddling and rolling mill at Einsal, with about 5,000,000 pounds' production, situated half a mile from the station Altena. These works have about the same water-power as those at Uetterlingsen, with 5 puddling-furnaces, 1 heating-oven, 1 lift-hammer, 1 bloom-roll, and 1 wire-roll.

IRON GIRDERS AND COLUMNS.

56.—The finest display of rolled girders and angle-iron of large sizes is made by the Burbach Furnace Company, (*Luxemburger Bergwerks und Saarbrücker Eisenhütten-Actien-Gesellschaft zu Burbach*,) which sends a variety of girders of full length, and elegantly supported upon a pyramidal iron frame, sustained by a special stone foundation independent of the floor of the building. The girders rest upon ornamental brackets, in the form of lions' heads. The following sizes of girders are noted:

18,000×355×142×13 millimeters.
18,000×262× 96× 9 millimeters.
18,000×200×100× 9 millimeters.
18,000×125× 75× 6 millimeters.

I 16,500×400×140×10 millimeters.
I 16,500×250×140×10 millimeters.
⊥ 16,500×200 120× 8 millimeters.
] 16,500×153× 58× 7 millimeters.

The same establishment sends several hollow wrought-iron columns, composite, made by riveting together flanged plates of the proper form; in short, the well-known American Phœnix wrought-iron column, invented and patented by Samuel J. Reeves, president of the Phœnix Iron Company, June 17, 1862.* The specimens here shown are highly

* Works at Phœnixville, Pa., John Griffen, superintendent.

creditable to the works, being of large size and well made. The largest (*a*) is square in section, and 12 inches internal diameter; another (*b*) is the same in form, but smaller and longer; and a third (*c*) is simply a flanged girder. The exact dimensions are below:

a. 19,200 $\times$ 280 $\times$ 86 $\times$ 18 millimeters.
b. 20,000 $\times$ 163½ $\times$ 70 $\times$ 13 millimeters.
c. 26,000 $\times$ 157 $\times$ 96 $\times$ 12 millimeters.

A long round column of similar construction, and very perfect, and remarkable also, as all such columns are, for rigidity, lightness, and strength, is shown in the Belgian section.

Columns of this construction and of greater dimensions than these are no novelty in the United States, for the Phœnix Iron-Works make a great variety of sizes and forms, and can fill orders on demand for columns 100 feet long, and from 3 inches to 3 feet in diameter, composed of segmental pieces, varying from ⅛ of an inch to 2 inches in thickness.

For more than ten years this description of column, or post, has been largely manufactured at the Phœnix Iron-Works, and many thousand tons of them have gone into the construction of wrought-iron bridges, viaducts, depots, warehouses, and other structures in various parts of the United States, Canada, Nova Scotia, and in South and Central America. All the top chords and posts of the trusses in the international bridge over the Niagara River, near Buffalo, are made of Phœnix columns. The same can be said of the intercolonial and all the new bridges on the Grand Trunk Railway in Canada, the Augusta bridge, in Maine, the Girard Avenue bridge, over the Schuylkill, the New River and Greenbrier bridges, in Virginia, the three wrought-iron bridges at Rock Island, Ill., and scores of others. Many important viaducts are composed almost entirely of those columns, as the Lyman and Rapallo viaducts in Connecticut; the Lyon Brook, Deep Gorge, and Block-house, in New York; Bullock Run and Bank Lick, in Kentucky; the Agua Venagas, in Peru. Many of these structures are of great length and depth, the last-mentioned being 580 feet long, and crossing a gorge 252 feet deep, over which the Lima and Arroya Railroad is carried. The over-head Greenwich Street Railway, in New York City, rests on a continuous line of these columns, though not by any means a good type, owing to their flaring tops and bottoms, made to suit the peculiar notions of the contractor of the railway.

57. The BURBACH WORKS were established in 1816, with four high furnaces. In 1872 there were about 1,550 workmen, and the production was over 1,000,000 hundred-weight of pig-iron, 418,000 hundred-weight rails, and 422,000 hundred-weight of shape-iron. Since 1867 the daily product of the furnaces has increased from 100 to 350 hundred-weight. Double-T girders are the specialty of the works. They also manufacture and exhibit wrought hoops, flanged inward, for lining circular mining-shafts. Some of these are from 10 to 12 feet in diameter, and 5 feet high. One hoop or ring is designed to set upon another, and in this way a high column may be built up.

IRON RAILWAY-TIES.

The Burbach Company also make an interesting exhibition of the different forms of iron they are manufacturing for "permanent way" for railroads by substituting iron for wooden ties. As this method, if extensively adopted, will lead to a greatly-increased demand for iron, it is specially interesting to iron-manufactures, as well as to railroad men, and merits a special notice. The simplest form is a cross-tie, rolled with a raised center and broad flanges, so as to have a firm bearing on the ground.

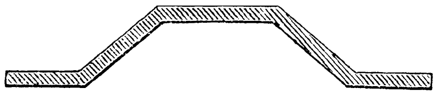


FIG. 50.—Iron railway-tie.

They are about a foot in width and half an inch thick, and appear to be intended to be firmly bedded in the earth without any special kind of filling. The rails with a suitable chair are bolted to the top.

Another form of "permanent way" consists in placing the iron sleepers on ties longitudinally under the rails, not across the track, but with it, in lengths of about twenty feet each, the parallelism and the uniform distance of the rails being maintained by tie-rods at intervals. The form of this iron bed-plate differs from the simple cross-tie above mentioned. It is wider, and is provided with sharp flanges projecting

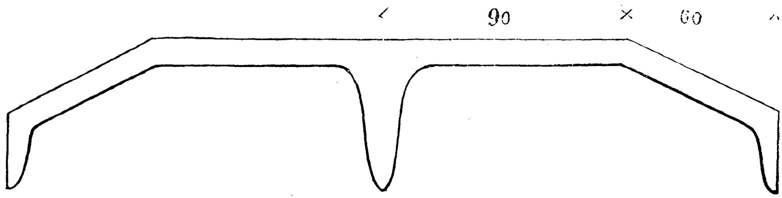


FIG. 51.—Cross-section of iron tie.

downward so as to penetrate the ground and hold it securely against side-thrusts. The breadth is 300 millimeters; depth, 60 millimeters from the top to the edge of the flange, equivalent to about 12 inches wide and 4 inches deep.

58. SCHALTENBRAND'S IRON CROSS-TIE.—C. Schaltenbrand, of Berlin, exhibits his proposed iron railway-tie, a hollow sleeper, filled in with sand or concrete, and to which the rail is attached by bolts. As early as 1870 Schaltenbrand described his method of making a railway entirely of iron, in a lecture at Cologne, and endeavored to prove that the wooden ties so universally used in railway-construction can be replaced by iron ties with profit. He stated eleven conditions essential to first-class construction which are realized in sleepers made wholly of wrought iron. He then thought, and still thinks, that iron ties are destined to replace wooden ones at no distant day, particularly where wood is growing scarce and dear and iron more abundant and cheaper. The relative economy can be easily ascertained by trial of the iron ties alongside of the ordinary wooden ones.

The ties, as exhibited, consist of plate-iron rolled or bent into the form indicated by the cross-section annexed, with a bottom-plate bent upward at the edges so as to catch and hold the edges of the upper plate.

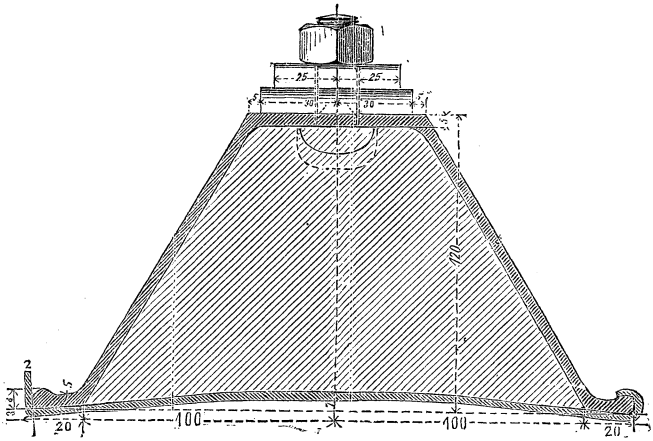


FIG. 53.—Section of iron railway-tie.

A flat piece of iron is rolled or welded upon the top, and the rail rests upon this. The method of attaching the rail is in this instance by clamps pressed firmly upon the foot of the rail on each side by bolts, as shown in the cross-section of the rail appended, but this is unimportant, as other methods of securing the rail to the tie may be adopted.

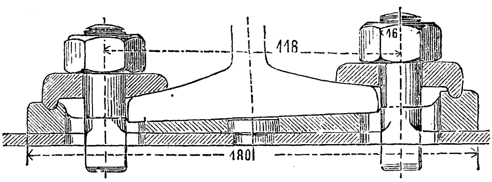


FIG. 54.—Cross-section of the foot of rail and the clamps.

The total breadth of the tie is about 10 inches; the height to the bottom of the rail 5 inches, and the thickness of the iron plate three-sixteenths of an inch at the sides and a trifle thicker at the top. The dimensions in millimeters are: breadth, 140 millimeters; height, 120 millimeters + 10 millimeters; thickness, 4 millimeters and 5 millimeter. The extreme length of the tie is 2,500 millimeters and the width of track 1,435 millimeters.

The tie is laid down before being filled in. The inventor proposes for filling either sand, loam, or sand into which small stones are crowded to make the filling firmer, or beton. These materials are to be rammed in from the ends, and the openings are closed finally by a tile of the proper form. It is also suggested that tiles or "shape-bricks" may be made to answer for the filling.

The bearing-surface or foundation of this tie is $25 \times .25 = .625$ square meter. Timber ties, it is observed by Schaltenbrand, in making the comparison between iron and wood, often measure only $2.5 \times .2 = .5$ square meter; so that the iron tie of the dimensions given may be assumed to have as broad a bearing upon the ground as the average wooden tie of Europe.

Before being laid, these ties are plunged into a bath of purified coal-tar, in order to fill the pores and prevent oxidation. The strength of the tie is increased by shrinking on the lower plate, by which the two parts become as one. The inventor states the strength of the tie at the weakest part, where pierced by the holes for the rail-bolts, at 50,400 centimeter-kilograms, and of the upper portion by itself at 32.200 centimeter-kilograms, while wooden ties, after five years' use, have only 15,000 centimeter-kilograms, and that half of the upper part of an iron tie may be rusted away and yet it will be as strong as such a wooden tie. He affirms that the sleeper itself is stronger than timber, and that, being uniform in size, the spaces are more even, and that the rail is more securely and conveniently attached than it can be upon wood. He claims that the iron ties, being heavier, and having greater bearing-surfaces, are not as easily displaced by moving trains as timbers, and that rails may be taken up and reset quicker and cheaper than when attached to timber ties. When the bed of the road is once packed, the sleeper can remain in its place as long as it lasts, as no jarring takes place. Irregularities in the level of the rails are easily corrected by putting little iron wedges under the rail upon the sleeper. After a short time there will not be any expense in packing the sand around the ties, and then their great durability will make all amends for the difference in cost over timber. The rusting iron with the surrounding bed-material and the inner filling-material will finally form a compact ferruginous mass, so that it will lie very firmly as long as it lasts.

The weight of the materials is as follows:

	Kilograms.
a. The upper part, cross section, 16,116 square centimeters, weight	31.30
b. The lower part, cross-section, 8,400 square centimeters, weight	16.34
c. 2 bed-plates, per piece, .63 kilogram	1.26
d. 4 clamp-plates, per piece, .18 kilogram	.72
e. 4 screws, per piece, .17 kilogram	.68
f. 1 connecting-link, .03 kilogram	.03
	50.33

Or about 50 kilograms, say 100 pounds. The cost of one tie now is about 7½ thaler, but when iron is lower the same weight of tie would not exceed 5 thaler. In comparison, oak ties, with four spikes, are reckoned at 3 thaler.

KRUPP'S DISPLAY.

59. The celebrated establishment of Krupp at Essen, Rhenish Prussia, fully sustains the prestige it has earned by its liberal participation in former exhibitions. In the magnitude, completeness, and excellence of the exhibition here made it shows that the spirit of enterprise which has characterized it in the past has kept pace with the rapidly-expanding proportions of the industry of iron and steel, and that the magnitude of its operations has been correspondingly increased. He makes a princely exhibition in a large building constructed at his own expense, in which the various costly objects are tastefully grouped, and so arranged that the visitor can have a general view of them from a raised platform at the entrance.

The following statistical data concerning the works, and the mines and smelting-works appertaining to them, and the notices of the objects exhibited are translated from the brochure printed at the printing-office of the works at Essen in 1873.

The cast-steel manufactory near Essen was established in the year 1810. It was conducted by Alfred Krupp from the year 1826, and taken by him on his own account in 1848.

The works have been gradually developed. At this present moment (January, 1873) the works cover a continuous area of more than 4,784,-000 square yards, of which about 900,000 square yards are covered in, and employ more than 12,000 workmen, independently of about 2,000 who are supplied by building-contractors.

In the mines and smelting-works belonging to the firm, there are employed a further number of about 5,000 workmen. Therefore, the total number amounts to about 17,000 men.

The number of officers and fixed employés is at present 739.

The quantity of cast steel produced in the year 1872 exceeded 125,000 tons.

The articles manufactured from this cast steel were axles, tires, wheels and crossings for railways; rails and springs for railways and mines; shafts for steamers; different pieces of machinery, boiler-plates, rolls, spring-steel, tool-steel, guns, gun-carriages, shot, &c.

There are now in operation 250 smelting-furnaces; 390 annealing-furnaces; 161 heating-furnaces; 115 welding and puddling furnaces; 14 cupola and reverberatory furnaces; 160 furnaces of other kinds; 275 coke-ovens; 264 smiths' forges; 240 steam-boilers, (besides 70 more now in course of construction.)

71 steam-hammers, viz:

Number	2	1	2	1	5	3	1	7	8	18	2	1	6	2
(each) cwt.	2,	3,	4,	7,	8,	10,	12,	15,	20,	30,	60,	65,	70,	75,
Number	3	4	1	1	1	1	1							
(each) cwt.	100,	110,	140,	150,	200,	400,	1000.							

286 steam-engines, viz:

Number	3	57	46	16	17	6	1	4	38	4	21	16	3	22	5
(each) H.P.	2,	4,	6,	8,	10,	12,	13,	14,	16,	18,	20,	23,	25,	30,	35,
Number	2	4	4	2	3	1	5	1	1	3	1				
(each) H.P.	40,	45,	60,	80,	100,	120,	150,	200,	500,	800,	1000,				

(representing altogether nearly 10,000 H. P.)

1056 machine-tools, viz: 362 turning-lathes; 82 shaping-machines; 195 boring-machines; 107 planing-machines; 42 punching and grooving machines; 32 pressing-machines; 63 grinding-machines; 31 glazing and polishing machines; 142 machines of different kinds.

In the year 1872 there were consumed:

Coals, 500,000 tons; coke, 125,000 tons; water, 113,000,000 cubic feet, supplied from several water-works; gas, 155,000,000 cubic feet, supplied by the gas-works of the establishment for 16,500 burners.

The works are in railway-connection with the Cologne-Minden, Bergisch-Märkisch, and Rhenish lines.

To facilitate the traffic on the works there are—

a. About twenty-four miles railways of usual gauge, with 180 sidings and 39 turn-tables, on which run 12 tank-locomotives of about 16 inches cylinder-diameter, and 530 wagons. Six more locomotives are now in course of construction.

b. About ten miles of small-gauge railways, of 30 inch gauge, with 147 sidings and 65 turn-tables. The traffic on these railways is carried on by means of horses, and of 3 locomotives of 6 inches cylinder-diameter, and 270 wagons. Four other locomotives are now being constructed.

The carriage department comprises, besides, 272 wagons, and altogether 191 horses, of which 60 to 80, are supplied by contractors.

To facilitate the communication between the several workshops, there are 30 telegraph-stations.

A permanent fire-brigade, consisting of 70 men, has also been instituted, who perform at the same time police-duty. There are 166 watchmen besides.

The general supply stores, under control of the firm, sell to voluntary purchasers, (*i. e.* to those belonging to the works,) for ready cash, provisions, clothing, drapery, boots, &c., at cost-prices. The receipts at the different stores amount at present to about £11,000 monthly, and are continually increasing.

Under this head may also be named 1 hotel, 3 beer-houses, 1 seltzer-water manufactory, 1 flour-mill, and 1 bakery with 2 steam-engines, producing at an average 85 tons of bread monthly.

Of the dwellings for the officers and workmen, there are for the former 206, for the latter 2,948, either inhabited or in course of construction. At the present moment there are living in these houses, the number of which is being rapidly increased, already more than 8,000 individuals. The existing boarding-houses offer board and lodging to 2,500 unmarried workmen, and other houses of the same description are now being built for the accommodation of 1,600 more.

The arrangements for the accommodation of the sick consist of 1 hospital containing 100 beds, and 1 epidemic hospital with 120 beds, all under the supervision of physicians especially engaged for the purpose.

A sick, burial, and pension fund has also been instituted for the workmen, *i. e.* for all those who receive wages from the firm. The latter contributes to this fund half the amount of the contributions paid in by the members, being, in addition, at the expense of providing pensions and support for those who have been rendered unfit for work in their service, and for the widows of their workmen. The total receipts in the year 1872 amounted to £16,000, the expenditure to £12,500, and capital in hand at the beginning of the present year (1873) to £19,348.

From another fund, members receive for their families free medical treatment against an annual payment of 3 English shillings.

Finally, the firm has organized a chemical laboratory, a photographic and a lithographic atelier, as well as a printing and book-binding establishment. In the printing-office there are 2 steam and 4 hand presses in operation.

Besides the cast-steel works near Essen, the firm possesses considerable mining and smelting works, which render the chief works independent of fluctuations in prices, and secure to it a regular and uniform supply of the best raw material. This head comprises;

1. Administration of Krupp's Mines:

a. Coal-pits: 1. Pit "Graf Beust;" 2. Pit "Ernestine;" 3. Pit "Friedrich Ernestine;" 4. Pit "Hanover;" as well as one-third in the Concessions "Humboldt" and "Diergardt" on the left bank of the Rhine.

b. Iron-ore mines: 1. In the mining-districts "Kirchen," "Daaden," "Siegburg," "Hamm," "Neuwied," together 64 mines, (No. 1 to 64;) 2. In the mining-districts "Wetzlar," "Weilburg," "Dietz," "Oberhessen," "Rheinhessen," and "Dillenburg," together 294 mines, (No. 65 to 358;) 3. In the mining-districts "Hamm a. d. Sieg," "Wied," "Unkel," "Coblenz," "Ründeroth," together 56 mines, (No. 359 to 414.) Total number of mines 414, with an area of more than 239,200,000 square yards.

The firm F. Krupp possesses, finally, important concessions of excellent iron-ore beds in North Spain, whence it is intended to import annually up to 300,000 tons of ore for the production of cast steel. To facilitate the importation, a railway in Spain nearly eight miles long, as well as several steamers, is already in course of construction.

2. The administration of Krupp's Smelting-Works comprises:

a. The Sayner and Oberhammer Smelting-Works, containing two blast-furnaces, one of them fed with charcoal. Both of them produce daily about twenty tons of "spiegeleisen" and "charcoal spiegeleisen." An iron-foundery and a machine-manufactory are connected with the Sayner Works.

b. The Mülhofer Smelting-Works on the Rhine, connected by a

branch line with the Rhenish Railway, terminating at the Engers Station, and containing 4 blast-furnaces (3 of them the latest Scotch construction) with pneumatic lifts. Each of them produces daily about 45 tons of spiegel, Bessemer, and fine iron.

c. The Hermanns Smelting-Works on the Rhine, near Neuwied, also connected by a branch line with the Rhenish Railway, has at present only one blast-furnace in operation; two others are, however, in course of construction.

d. The Bendorf Smelting-Works with one blast-furnace of an older pattern, are at present not in operation.

e. The Johannes Smelting-Works, formerly the property of the German-Dutch Joint-Stock Company for Smelting and Mining, near Duisburg on the Rhine, produce daily, in four blast-furnaces, from about 140 to 160 tons. The construction of six more furnaces has been commenced, and the works are in connection with the Rhenish and the Bergisch-Märkisch Railway.

These works have also 140 coke-ovens in operation, and 120 more in course of construction.

Krupp's smelting-works produce, accordingly, at the present time, with eleven blast-furnaces, nearly 10,000 tons pig-iron per month.

60. Catalogue and description of the objects exhibited:

(1.) One crucible cast-steel block, (1,800 crucibles each containing about 60 pounds,) 54 inches octagonal, weighing 52,500^k = 52½ tons.

This casting, originally cylindrical, has been reduced to the present octagonal form by forging under a 50-ton hammer to illustrate the malleability of the material. Cuts were made in four different places, while in a red-hot state, to show, when broken off later, the density and soundness of the cast steel. This block, of gun-metal quality, is intended for the body of the gun of 37^{cm} (14 inches) caliber, and receives the required form by further forging.

In London, 1851, the firm exhibited a crucible cast-steel block, weighing 2,250^k. = 2¼ tons, and received the only council-medal awarded in the cast-steel department; in Paris, 1855, a block of 10,000^k. = 10 tons; in London, 1862, a block of 20,000^k. = 20 tons; in Paris, 1867, a block of 40,000^k. = 40 tons.

All articles produced in the establishment, with exception of the disk-wheels and crossings, which are cast in molds, are forged and wrought by tools from similar more or less heavy castings of circular cross-section.

(2.) One locomotive straight axle of crucible cast steel, in the forged state, (pattern of the Northeastern Railway, in Switzerland.)

(3.) One forged tender-axle of crucible cast steel, (pattern of the same railway.) The body of this axle is forged complete under the hammer, and requires no further workmanship.

(4.) Six carriage-axles of crucible cast steel, forged according to the dimensions approved by the German railways. The body is, in the

same manner, forged complete under the hammer. Production in 1872 of unmounted axles in the forged and finished state, 16,450 axles.

The first extensive trials with Krupp's cast-steel axles were made in the year 1850, at Borsig's works, Berlin, by a commission appointed at a meeting of German railway-engineers, (pamphlet by Landbaumeister Dihm, Berlin, 1850, printed by J. Petsch.) Although the trials were very favorable, Krupp's cast-steel axles were not generally adopted until the year 1861 and 1862. The production increased, however, rapidly, so that the firm supplied, in 1865, more than 11,000, while the supply during last year (1872) exceeded 16,000 axles.

(5.) Two unwelded rings of crucible cast steel, forged from solid blocks by making a cut in the middle and opening them out under a hammer. In accordance with this method of manufacture, patented by the firm in 1853, the railway-tires receive the required dimensions and sections by rolling, as shown by—

(6.) Two samples of tires, ready rolled and complete up to turning. Also, one tire ready turned. Production in 1872, more than 45,000 tires.

Up to the year 1853, only welded-iron and fine-grained iron tires were manufactured. Krupp's establishment was the first that introduced the unwelded cast-steel tires for use on railways, and caused them to be generally adopted. Since the expiration of the above-named patent, this method of manufacture has, in principle, been imitated by all works manufacturing cast-steel tires.

(7.) Two unwelded angle-rings of crucible cast steel, for steam-boilers, made in the same manner as the tires.

(8.) Two coupling-rods and two connecting-rods, forged from crucible cast steel. Pieces of machinery of this description are supplied by the works in the forged state only, as here shown.

(9.) Four piston-rods, forged from crucible cast steel. (Pattern of the Central Railway, in Switzerland.)

(10.) Two slide-bars of crucible cast steel, in the forged state.

(11.) Two pistons, forged from crucible cast steel. (Pattern of the Niederschlesisch-Märkisch Railway.)

(12.) One locomotive crank-axle of crucible cast steel, with single, and one with double-bearings. Both axles are in the finished state.

Those crank-axles, which were supplied to the French Orleans Railway during 1857, 1858, and 1859, have, up to the present year, run over 500,000 kilometers, (312,000 miles,) and are still in good working order.

(13.) One locomotive eccentric crank, and one driving-wheel crank, both of crucible cast steel, in the finished state. These pieces of machinery are supplied by the works in the rough-turned or finished state.

(14.) One set of locomotive and tender axles, pattern for engines C. IV of the Northeastern Railway, in Switzerland, consisting of—

a. One driving-axle of crucible cast steel, ready fitted with tires, cranks of same material, spoke-wheels, nave included, of wrought iron, and cast-iron counter-weights. Weight, 2,160^{k} = about 43 cwt.

b. Two coupling-axles of crucible cast steel, ready fitted with tires and crank-pins of the same material; spoke-wheels, nave included, of wrought iron, and cast-iron counter-weights. Weight of each, 1,900^k = about 38 cwt.

c. Two tender-axles of crucible cast steel, body forged, ready fitted with tires of same material, and spoke-wheels, nave included, of wrought iron. Weight of each, 1,200^k = about 24 cwt.

Production in 1872 of complete sets of locomotive and tender-axles, 475.

(15.) Two carriage-axles of crucible cast steel, body forged, ready fitted with tires of same material, and spoke-wheels, nave included, of wrought iron. Weight of each 950^k = about 19 cwt.

Axles and tires according to the dimensions approved by the German railways.

Production in 1872, 4,650 sets.

(16.) Two carriage-axles of crucible cast steel, ready fitted with disk wheels, cast in molds, of same material. Weight of each, 1,000^k = about 20 cwt.

Production in 1872, 4,340 sets.

(17.) A collection of spring-steel fractures and cross-sections of spring-steel. This steel is supplied in bars of any section not less than 10^{mm} thick and 65^{mm} wide.

Production in 1872, 3,000,000^k = about 3,000 tons.

(See fractures and cross-sections under No. 26.)

(18.) A collection of cast-steel springs for locomotives, tenders, and carriages:

a. Two locomotive-springs with ten flat leaves, welded links, and bored bolt-holes; two of the same with 14 flat leaves, with welded links and bored bolt-holes.

b. Two collision-springs with 9 flat leaves; one with 13 ribbed leaves.

c. One tender spring with 9 flat leaves.

d. One passenger-carriage spring with 5 ribbed leaves and rolled eyes; one with 6 flat leaves and rolled eyes; one with 7 flat leaves and welded eyes.

e. One luggage-wagon spring with 5 flat leaves and rolled eyes; one with 6 ribbed leaves and rolled eyes; four with 7 ribbed leaves and rolled eyes; four with 8 flat leaves and rolled eyes.

Production in 1872, 38,600 springs.

(19.) One reversible double crossing of crucible cast steel, cast in a mold and ready to be laid down. (Pattern of the Cologne-Minden railway.) These crossings have been introduced on many German and transatlantic railways.

(20.) Bessemer-steel rails:

The manufacture of these rails is illustrated by a Bessemer casting from which octagonal blocks are forged, as shown by the exhibited sample.

These blocks then receive by rolling the required form for rails, as also shown, are cut off according to weight, and rolled to the prescribed

section; two rails rolled in this manner, the ends of which are not cut off, are also exhibited; two rails ready cut and punched according to the Cologne-Minden section V; one for Cologne-Minden switches; one for Oberschlesisch switches.

The annual production of the works of steel rails has increased from 100 tons to 50,000 tons in 1872. This increase is no doubt the best proof of the favorable results obtained from the use of steel rails on railways, and it may be assumed that these rails are now generally introduced.

Besides the manufacture of steel rails for locomotive-railways, the manufacture of those of smaller sections, from 11 to 22 pounds per yard, for mining purposes, has also considerably increased.

Production in 1872, 2,000 tons.

Here follows a collection of rail-fractures of different kinds.

(21.) Two switches of Bessemer steel, (section of the Oberschlesisch and Niederschlesisch-Märkisch Railways,) ready planed, as same are supplied by the works, also in the finished state.

(22.) One double crank-shaft of crucible cast steel, forged also from a solid block and finished, for a transatlantic steamer. Weight, 9,000^{k}; length, 7.650^{m}; diameter, 0.38^{m}.

(23.) One trunnion-hoop, unwelded, of crucible cast steel, in the forged state.

(24.) 2 pressed sides for field-gun carriages, of cast steel, 6^{mm} and 10^{mm} thick.

(25.) Rolls and rolling-machines:

The rolls and rolling-machines exhibited illustrate the most usual forms and dimensions used in this branch of manufactory, one of the oldest of the establishment.

1. 1 pair of rolls, A, 65 by 40^{mm}.
2. 1 pair of rolls, B, 78 by 52^{mm}.
3. 1 pair of rolls, C, 157 by 105^{mm}.
4. 1 pair of adjusting-rolls, 95 by 148^{mm}.
5. 1 pair of rolls for mint purposes, 210 by 210^{mm}.
6. 1 roll for manufacturing percussion-caps, 61 by 72^{mm}.
7. 1 pair of rolls, polished, 420 by 462^{mm}.
8. 1 pair of rolls, to be engraved for rolling spoons.
9. 1 pair lace-rolls, polished.
10. 1 rolling-machine, A, with rolls 65 by 40^{mm}.
11. 1 rolling-machine, B, with rolls 78 by 52^{mm}.
12. 1 rolling-machine, C, with rolls 157 by 105^{mm}.

For goldsmiths:

13. 1 tinsel-rolling machine, 157 by 52^{mm}.
14. 1 lace-rolling machine, 40 by 210 to 58 by 126^{mm}.

All rolls being hardened, excepting those for rolling spoons.

(26.) A collection of fractures of hardened tool-steel, as well as various other fractures of manufactured articles, such as axles, tires, crossings, and disk-wheels; mint-dies with polished surface.

(27.) A series of various classes of ore, pig-iron, and pig-steel iron, from the mines and smelting-works of the firm, used in the manufacture of steel.

61. *Artillery material.*—The guns are manufactured from crucible cast steel, of a quality especially adapted for the purpose, and are, those of the smallest calibers excepted, constructed according to the built-up system. All guns have Krupp's round wedge.

The naval and coast-gun carriages are generally manufactured from wrought iron; only particular parts, such as the axles, axle-trees, cylinders, and piston-rods of the hydraulic buffer, and the slide-rollers of the coast-gun carriages, being made of cast steel. Cast iron is only used for small truck-wheels.

(28.) $30\frac{1}{2}^{cm}$ gun on coast carriage.—Caliber, 305^{mm}; length of gun, 6.7^{m}; length of bore, 5.77^{m}; weight of gun with wedge, $36{,}600^{k}$; preponderance, 0.

The gun has 72 parallel grooves, with 4.5^{mm} width of lands, and a uniform twist of 21.79^{m} in length.

Weight of charged steel shell, 296^{k}; weight of charge, (prismatic powder,) 60^{k}; initial velocity, 465^{m}.

Weight of charged common shell, 257^{k}; weight of charge, (prismatic powder,) 50^{k}; initial velocity, 460^{m}.

The carriage is intended for earth-parapets of 1.9^{m} height, and has a height of 2.380^{m}. To check the recoil, an hydraulic buffer is used. The running-out of the gun after discharge is self-acting.

The projectile is lifted by means of a movable crane with windlass, which is arranged on the right-hand side of the slide, and brought on to the bottom of the gun.

The elevation (+ 17°, — 7°) is taken by means of a toothed elevating-arc on the upper part of the carriage. For training, the end of the slide is provided with a chain-gear.

By this apparatus the gun can be very easily and quickly served.

To run-in the gun, a rope-windlass may be placed, if necessary, on each side of the slide behind.

	Kilograms.
Weight of carriage	5,650
Weight of slide	15,350
Total weight	21,000

A $30\frac{1}{2}^{cm}$ gun of the foregoing description was tried in the month of February, 1873, in the presence of a commission of Prussian and Austrian artillery officers, with 5 rounds of 20^{k}, 7 rounds of 40^{k}, 6 rounds of 50^{k}, 207 rounds of 60^{k}, 5 rounds of 65^{k}; charges of prismatic powder, and with solid shot weighing from 300 to 305^{k}. The gun was after this trial, with exception of slight gutterings (*Ausbrennungen*) in the chamber, perfectly uninjured and ready for further trials, which are to take place on the lately-acquired practice ground of the establishment, $7{,}000^{m}$ in length, as soon as it can be properly prepared for the purpose.

The carriage was, at the end of the trial, also uninjured, excepting a very trifling crushing of the points of the wedge-rails on the girders of the slide.

(29.) 28^{cm} howitzer on coast-carriage.—The gun is constructed for being placed in coast-batteries. Caliber, 280^{mm}; length of gun, $3,200^{m}$; length of bore, $2,520^{m}$; weight with wedge, $10,000^{k}$; preponderance, 0.

The gun has 72 parallel grooves, with 4.5^{mm} width of lands, and a uniform twist of 11.2^{m}.

Weight of charged common shell, 199^{k}; maximum weight of charge, 20^{k}. The carriage of the gun admits of an elevation of 75°.

The carriage differs from the coast-gun carriages principally in that the whole of the under face of the slide lies in the platform on firing, so as to extend the impact of recoil over a larger surface. For training, the slide is placed upon rollers, for which reason the rear slide-trucks are put on eccentric axles.

The projectile-crane, training-gear, hydraulic buffer, and self-acting running-out apparatus are the same as in the other coast-gun carriages. The elevating-gear is also similarly constructed.

Weight of the whole carriage, $9,220^{k}$; height, $1,675^{m}$.

(30.) Short 26^{cm} ship-gun on battery-carriage.—Caliber, 260^{mm}; length, 5.2^{m}; length of bore, 4.420^{m}; weight of gun with wedge, $18,000^{k}$. Preponderance, 0.

The gun has 64 parallel grooves, with 4.25^{mm} width of lands, and a uniform twist of 18.2^{m}.

Weight of charged steel shell, 184^{k}; weight of charge, (prismatic powder,) 37.5^{k};. initial velocity, 450^{m}.

Weight of charged common shell, 159^{k}; weight of charge, (prismatic powder), 30^{k}; initial velocity, 450^{m}.

This gun has a carriage for use in a broadside-battery of iron-clads. The carriage differs from the former ship-carriages for similar purposes, principally in that the hydraulic buffer and apparatus for self-acting running-out are contrived similarly to those of coast-gun carriages. The hydraulic buffer is so arranged that the gun, with the upper part of the carriage, can be retained at once on any part of the slide.

The training is effected by a cog-wheel, which works into a cog-racer in the deck, and is moved by a worm-wheel, so as to dispense with an especial brake to retain the gun in the required direction. For elevation, there is arranged on both sides of the gun a cogged elevating-arc; both are, however, moved simultaneously from the left side of the carriage by a hand-wheel. In order to relieve the ship's side in firing, the recoil is partially received from the grooved rollers by ribs on the upper face of the deck-racers, and from a strong hook, which ties the fore part of the slide down to the strong projecting lip of the front racer.

Total weight of carriage, $8,756^{k}$; height, $1,220^{m}$.

(31.) Long 24^{cm} gun on battery-carriage for casemate-ships.—Caliber, 235.4^{mm}; length of gun, 5.23^{m}; length of bore, 4.54^{m}; weight of gun, with wedge, $15,500^{k}$; preponderance, 0.

The gun has 32 grooves, whose breadth increases toward the breech, with a width of lands of 3.9^{mm} at breech and 7.85^{mm} at mouth. The twist is uniform, of 16.48^{m} length.

Weight of charged steel shell, 135^{k}; weight of charge, (prismatic powder) 24^{k}; initial velocity, 430^{m}.

Weight of charged common shell, 118.5^{k}; weight of charge, 20^{k}; initial velocity, 424^{m}.

The gun is mounted on a battery-carriage for casemate-ships. Owing to its position in one of the obtuse angles of the casemate, so as to be capable of firing through a broadside and a bow or stern port, it was necessary to make arrangements for a change of ports. This is done by means of a turn-table, on which the gun rests with the middle slide-supports and the rear slide-rollers, after the fore slide-rollers have been lifted correspondingly by an hydraulic lifting-jack, fixed under the slide for this purpose. To facilitate the unshackling of the pivot-bar on the change of ports, it is divided, and at the joint an easily removable bolt is put on.

To check the recoil, the carriage is provided with an adjustable plate-compressor. A chain running-in-and-out gear is applied on both sides of the slide-end. For training, the pinion of the cog-racer is moved by the same cranks which are used for the above-mentioned chain-gear.

The elevation is taken by means of a cogged elevating-arc.

Height, $1,195^{m}$.

	Kilograms.
Weight of carriage	2,344
Weight of slide	5,466
Total weight	7,810

(32.) Long 21^{cm} gun on coast-carriage.—Caliber, 209.3^{mm}; length of gun, 4.708^{m}; length of bore, 4.106^{m}; weight of gun, with wedge, $10,000^{k}$; preponderance, 0.

The gun has 30 grooves, whose breadth increases toward the breech, with 3.4^{mm} width of lands at breech and 7.3^{mm} at mouth. The twist is uniform, of 14.23^{m} length.

Weight of charged steel shell, 95^{k}; weight of charge, (prismatic powder,) 17^{k}; initial velocity, 430^{m}.

Weight of charged common shell, 79^{k}; weight of charge, 14^{k}; initial velocity, 430^{m}.

The gun is mounted on a coast-carriage of a description similar to that of the $30\frac{1}{2}^{cm}$ gun.

Height, $2,015^{m}$.

	Kilograms.
Weight of carriage	2,090
Weight of slide	5,110
Total weight	7,200

(33.) 21^{cm} siege-gun, with slide-carriage.—Caliber, 209.3^{mm}; length of gun, 3.400^{m}; length of bore, $2,910^{m}$; weight of gun, with wedge, $3,900^{k}$; preponderance, 0.

The gun has 30 grooves, whose breadth increases toward the breech, with 3.7^{mm} width of lands at breech and 7.5^{mm} at mouth. The length of twist is 12.36^{m}.

Weight of charged common shell, 79^{k}; weight of charge, (prismatic powder,) 6.5^{k}; initial velocity, 300^{m}.

The carriage for this gun is a short slide-carriage, in all essential points similar to the coast-carriages. The slide, when in battery, rests in front on the pivot-block, behind on two rollers which can be moved, for the purpose of training, by means of handspikes. The cogged elevating-arc admits of 27° elevation and 6° inclination. The projectile-crane, hydraulic buffer, &c., are similar to the coast-carriages. This gun can be made available for transport. For this purpose a strong axle with large wheels is placed in the axle-supports, after the gun and carriage have been run in on the slide; then the fore end of the slide is raised by means of a lifting-apparatus, which is permanently fixed on the slide, consisting of a screw with worm-wheel gearing; and finally the rear end of the platform is limbered up. The transport rear wheels have a diameter of 2.046^{m} and a breadth of 0.180^{m} in the rim. The distribution of the weight resting on hind and fore wheels is in proportion of 4 to 1. To lighten the transport-wagon, the slide-rollers may be carried separately; the projectile-crane may be turned over. For transport by rail, the limbered-up carriage can be easily placed on a 10-ton luggage-wagon. The bed, made of oak beams and provided with pivot-block and racer, can be carried on an ordinary luggage-wagon. As soon as the gun has been carried to its proper place over the bed in the battery, it is unlimbered, and then the rear slide-rollers are lowered down on the racer by means of a windlass; the slide is afterward let down in front upon the pivot-block, and the transport axle and wheels are removed.

Height in battery, 1.9^{m}.

	Kilograms.
Weight of carriage	922
Weight of slide	1,728
Total weight	2,650
The limbered-up gun with side-arms weighs	8,160
The bed complete weighs	2,080

(34.) Long 17^{cm} gun on upper-deck carriage.—Caliber, 172.6^{mm}; length of gun, $4,250^{m}$; length of bore, $3,780^{m}$; weight of gun with wedge, $5,600^{k}$; preponderance, 0.

The gun has 48 parallel grooves, with 3.5^{mm} width of lands, and a uniform twist of 11.2^{m}.

Weight of charged steel shell, 55^{k}; weight of charge, (prismatic powder,) 10^{k}; initial velocity, 460^{m}.

Weight of charged common shell, 45^k; weight of charge, (prismatic powder,) 10^k; initial velocity, 465^m.

The upper-deck carriage for this gun is to be placed in the bow or stern of iron-clads, and provided with contrivances so as to be moved easily and quickly into a rear position. To check the recoil, a plate-compressor is used. For training, the slide, which usually rests on the supports, is placed on the rollers, for which purpose the rear slide-rollers are mounted eccentrically.

Height, $1,020^m$.

	Kilograms.
Weight of carriage	1,255
Weight of slide	2,235
Total weight	3,490

(35.) 15^{cm} siege-gun on wheel-carriage.—Caliber, 149.1^{mm}; length of gun, 3.44^m; length of bore, $3,040^m$; weight of gun with wedge, $3,000^k$; preponderance, 1^m from the trunnion, 25^k.

The gun has 36 grooves, with 3^{mm} width of lands at breech and 5.5^{mm} at mouth. The length of twist is 9.7^m.

Weight of charged common shell, 28^k; weight of charge, (prismatic powder,) 6^k; initial velocity, 470^m.

The carriage for this gun is constructed as a wheel-carriage. The brackets are made of plates and angle-iron. The elevating-screw admits of 35° elevation and 5° inclination. As a peculiarity in this carriage may be named the hydraulic buffer, which, on discharge, checks the recoil to about 1^m or less. The buffer-cylinder can be moved vertically, being fastened to the brackets at one-third of their length from behind. The piston-rod can be moved vertically and horizontally, by means of a pivot-bolt connected with an anchor, partly imbedded in the parapet.

Height, $1,830^m$; weight of carriage, $1,845^k$.

(36.) Long 15^{cm} gun on ship-carriage.—Caliber, 149.1^{mm}; length of gun, 3.85^m; length of bore, 3.43^m; weight of gun with wedge, 4.000^k; preponderance at the commencement of the rounding of the wedge, 75^k.

The gun has 48 parallel grooves, with 3^{mm} width of lands and 9.7^m length of twist.

Weight of charged steel shell, 35^k; weight of charge, (prismatic powder,) 8^k; initial velocity 460 .

Weight of charged common shell, 28^k; weight of charge, 6.5^k; initial velocity, 465^m.

The carriage of this gun is made for broadside use on sloops of war and similar vessels. It is a slide-carriage. To check the recoil, a plate-compressor is used, and a breeching as reserve. The elevation is effected by a cogged elevating-arc, and the training by means of tackles, for which side-eyes are provided on the rear end of the slide. The slide rests usually by supports on the racers; for training, it is lifted upon the rollers.

Height, 0.960^m.

	Kilograms
Weight of carriage	1,505
Weight of slide	935
Total weight	2,440

(37.) 12^{cm} gun on ship-carriage.—Caliber, 120.3^{mm}; length of gun, 2.925^{m}; length of bore, 2.602^{m}; weight of gun, with wedge, 1,400^{k}; preponderance, 100^{k}.

The gun has 18 grooves, whose breadth increases toward the breech, with 2.5^{mm} width of lands at breech and 6.5^{mm} at mouth. The length of twist is 8.42^{m}.

Weight of charged steel shell, 15.5^{k}; weight of charge, (large-grained powder,) 3.5^{k}; initial velocity, 450^{m}.

Weight of charged common shell, 15.5^{k}; weight of charge, (large-grained powder,) 3^{k}; initial velocity, 450^{m}.

The carriage for this gun is a wheel carriage constructed for the main or upper deck of small vessels. To check the recoil, an hydraulic buffer is applied, similar to that of the 15^{cm} siege-carriage. The buffer-cylinder, movable vertically and horizontally, hangs on the pivot-bolt; the piston-rod is fastened to the carriage. A strong breeching is provided as reserve. The carriage rests usually on four rollers; for training, the rear rollers, which are mounted eccentrically, are lifted, whereby the weight is transferred to a training-roller.

The elevation is taken by means of a cogged elevating-arc, which admits of $+15°$ and $-10°$.

Height, 0.900^{m}; weight of carriage, 895^{k}.

(38.) 9^{cm} field-gun with carriage.—Caliber, 91.5^{mm}; length of gun, 2.040^{m}; length of bore, 1.819^{m}; weight of gun, with wedge, 425^{k}; preponderance, 50^{k}.

The gun has 16 grooves, whose breadth increases toward the breech with 2.5^{mm} width of lands at breech and 6.5^{mm} at mouth. The twist is 4.53^{m}.

Weight of charged shell, 6.9^{k}; weight of charge, (cannon-powder,) 0.6^{k}; initial velocity, 322^{m}.

The gun-carriage has riveted wrought-iron brackets. Weight of carriage, (without accessories,) 546^{k}. The elevating-screw admits of an elevation of $+15\frac{3}{16}°$ and 8°.

(39.) 8^{cm} field-gun, with carriage.—Caliber, 78.5^{mm}; length of gun, 1.935^{m}; length of bore, 1.728^{m}; weight of gun, 295^{k}; preponderance, 70^{k}.

This gun has 12 grooves, whose breadth increases toward the breech, with 2.5^{mm} width of lands at breech, and 6.5^{mm} at mouth. The twist is 3.62^{m} long.

Weight of charged shell, 4.3^{k}; weight of charge, (cannon-powder,) 0.5^{k}; initial velocity, 357^{m}.

The carriage for this gun has also riveted brackets. Weight of carriage, (without accessories,) 460^{k}. The elevating-screw admits of $13\frac{15}{16}°$ elevation, and 8° inclination.

(40.) 6^{cm} mountain-gun on carriage.—Caliber, 60^{mm}; length of gun, 1.250^{m}; length of bore, 1.130^{m}; weight of gun with wedge, 107^{k}; preponderance, 14^{k}.

This gun has 18 parallel grooves, with 3^{mm} width of lands and 2.10^{m} length of twist.

Weight of charged shell, 2.3^{k}; weight of charge, 0.2^{k}; initial velocity, 300^{m}.

The carriage has wrought-iron brackets, cast-steel axle, and wooden wheels. On the naves of the axle there are conical friction-brakes.

Weight of carriage, 109^{k}; height, 0.660^{m}.

The elevating-screw admits of 21° elevation and 10° inclination.

(41.) Ammunition:

(*a.*) Shells. Forged of crucible cast steel for every one of the exhibited guns; both whole ones and cross-sections.

(*b.*) Common shells of cast iron for all exhibited guns; some in cross-sections, all with complete percussion-fuses.

(*c.*) Models of cartridges and of prismatic powder.

The specific weight of the prismatic powder is, for the 26^{cm}, 28^{cm}, and $30\frac{1}{2}^{cm}$ guns, from 1.72 to 1.76; for those of smaller calibers, from 1.62 to 1.66.

62. BUTTGENBACH'S BLAST-FURNACES.—The brothers Conrad and Franz Buttgenbach, of Neuss, in Rhenish Prussia, exhibited a model and drawings of their new method of constructing blast-furnaces, patented in Austria, France, Belgium, England, and America. The model, about 4 feet high, is very perfect, and is sold to the Imperial Mining Museum at St. Petersburg. Inasmuch as Mr. Buttgenbach presented with the model a full description of his furnace in print, and reported specially upon it to the Iron and Steel Institute, I prefer to present it in full in his own words:

"In 1859, I undertook the management of the Neuss Smelting-Works, situate on the Lower Rhine, Rhenish Province, and there I found a high blast-furnace, then just recently erected, which had not yet been in active operation.

"An engineer, late of the Liegen district, who had seen all the blast-furnaces of that part of the country set up against steep hills, supplied with raw materials brought up to the required level by means of carts and wheelbarrows, and having steam-boilers and air-heating apparatus mostly on a level with the furnace-mouth, when charged with the duty of sketching out a plan for the work above mentioned, in his inability to free himself from the influence of this (old-fashioned) notion, actually projected and caused to be built on a level plane a stack of masonry measuring 40 feet square at its base, by 40 feet in height, rising perpendicularly.

"At the center of this stack was placed the blast-furnace, its hearth being accessible only by means of very narrow embrasures; upon the

platform of the furnace-mouth two steam-boilers have been erected, as well as a draught-flue, the idea being, probably, that the descent was to take place contrary to the natural tendency of the gases.

"This stack being altogether too bulky for me to attempt to remove it bodily, I simply contented myself with clearing away as much of it as possible round about the hearth, and in such condition as I then brought it to, our blast-furnace has been continuously at work ever since 1860, under my management. The difficulty of working with a furnace similarly blocked in, but more especially the fact resulting from the experiences of two or three years' operations that the fire-proof facings had completely worn away, impelled me to attempt the construction of a blast-furnace, the heart of which should be readily accessible on all sides, and following up this idea, I built up at our works a blast-furnace 50 feet high and 17 feet in diameter at the boshes.

"In justice to my brother, a metallurgical engineer, I must not here omit to state that, in elaborating and finally determining upon my plans, I had the advantage of his suggestions and valuable advice.

"In 1867, a model of the above-named blast-furnace was exhibited in Paris, and I had the satisfaction, not only of being complimented upon my idea by a great number of engineers of every nationality, qualified to express an opinion on the subject, but of having conferred upon me, likewise, the distinction of an honorable mention on the part of the jury of the exhibition. The articles contributed to the *Revue Industrielle* of the exhibition of 1867 by Professor Jordan, who occupied the chair of metallurgy at the *Ecole centrale* in Paris, have brought my system into notice in France. Since 1867, six French iron-masters have adopted my system, and have constructed 9 blast-furnaces from my plans and in accordance with my suggestions. Both in Germany and Austria my system has likewise been introduced with success at several iron-works.

"The fundamental idea of this mode of construction and the advantages of the system may be summed up as follows, viz:

"1st. The mason-work of the stack is quite independent of the blast-furnace proper. Each ring or course of bricks constituting the hearth, boshes, and inside wall is readily accessible and free from any casing, except as regards a small portion, measuring from 3 to 4 feet in height, at the widest section of the blast-furnace.

"Consequently, the whole of the above several parts are completely bare and easily reached for any purpose required, even while the furnace is in active operation. This feature conduces to the duration of the furnace, for in case of need any injured part can be repaired, even when the furnace is at work.

"2d. The inside wall and the upper part of the boshes being cooled by the atmosphere having access thereto, they remain in their normal condition without wear, and do not become unduly heated at any time, being, therefore, indefinitely kept in a state of preservation, since there never occurs a fusion of materials at this height.

"3d. The hearth, and the lower portions of the boshes, being apt to suffer after a certain time, from the destructive action of the materials in a melting state, may be replaced without any difficulty whatever while the work is going on, so that there is no occasion to apprehend any extinction of the fires so long as the in-wall is not destroyed. If putting out the fires should at any time become necessary, the hearth and the boshes could be renewed without affecting the in-wall injuriously.

"4th. Each particular brick being accessible during the working of the furnace, and the progress of the fire easily ascertained, corrosions can be obviated by cooling down with water thrown on the several parts, or by means of water-vessels or tuyeres wherein the water circulates placed within these parts as far as the inside of the furnace, whereby the wear and tear can be checked.

"5th. The utilization of the gas at the furnace-mouth can be so managed as to make it yield the best results. The pillars supporting the platform of the furnace-top are gas-pipes, and drop into sheet-iron vessels fixed to the summit of the base of the stack, where it slopes away. These vessels are open on one side, so that when filled with water up to a certain height, they can be shut down by means of a valve, measuring a few centimeters square. The gas issuing forth out of the furnace-mouth finds its way into these receptacles, and in its passage through them travels over a large surface of water. Here it deposits the dust, while a great part of the water suspended in the gas, in a state of vapor, is condensed. Consequently, the gas reaches its destination in a highly-purified condition, and may yield the very best results in those parts where it is desired to make use of it.

"The arrangement of the said water-receptacles allows of the withdrawal of the dust or grit deposited while in full working, and in the event of an explosion, the area of from five to six millimeters of the water-column paralyzes, as though it were a gigantic valve, any injurious effects. In point of fact, instead of dreading we rather wish for explosions from time to time, since they serve the purpose of clearing off the dust and grit that may still be clinging to the inner walls of the pipes. Moreover, there is the advantage of confining these subsidiary appliances to a spot on the works which does not in any way interfere with the general progress of the manufacture.

"6th. The gas-pipes being supporters also of the platform surrounding the furnace-mouth or top, render the said platform independent of the blast-furnace proper, and that without involving any special outlay.

"In the first days of this erection, critics expressed a fear that the chilling of the parts thus exposed in this blast-furnace would be achieved only at the cost of a greater consumption of fuel. But, contrary to such apprehensions, experience has amply shown that blast-furnaces, the brick-work of which at the core is in direct contact with the outer air, use less fuel than do those that are protected by strong mason work, or

shut in by means of a second inner casing with a lining of sheet-iron; and the opinion expressed by me from the very beginning explains this result. For, in point of fact, a blast-furnace should form at its lower part a smelting-crucible, and it is generally known that every expedient available is brought into use for the purpose of cooling the walls of this portion of the structure. The boshes are a kind of retort, wherein the ore is reduced by means of its contact with the fuel, and the in-wall is like unto the neck of a retort, and in which the ore is prepared by the action of a moderate heat and contact with the reducing gases.

"If the ore sinking into the in-wall section requires a spongy condition, and continues in this condition without undergoing semifusion, it is quite obvious that the effect produced by the gas must be infinitely greater, and that the ore must descend into the zones of the boshes and of the hearth in a much better state of preparation than if the heat of the in-wall had partially converted it into cinder, so that the reducing gas must pass on, incapable of action upon such ore, except superficially. The ore, thus brought into a better state of preparation, must of necessity require less fuel in order to its perfect fusion.

"Moreover, in the event of cinder being formed at the in-wall zone, it will adhere to the walls and produce concretions, which always impede the proper working of a blast-furnace. When the ore sinks with regularity the smelting-process is facilitated, whereby a further saving of fuel is effected.

"The truth of the foregoing assertions has been fully established by the experience of eight years' working at our works. Concretions have never been noticed, and the proportion of fuel required for the furnace, constructed upon the new principle, has always been from 10 to 15 per cent. smaller, *cæteris paribus*.

"When good coke has been used, excellent No. 1 foundery-pigs have been produced from ores yielding 35 per cent., the consumption of coke being in the ratio of 11 parts to 10 part of pig, at a temperature of 350° centigrade, under blast, while in the case of white pig it is one part less of good coke to every part of pig. Touching the fears entertained of undue chilling in severe seasons, the following facts have served to dispel them *in toto*:

"The blast-furnace at the Neuss Works has more than once been suddenly blown out for several weeks, owing to causes quite foreign to its working capabilities. Three of these suspensions occurred during the war in the year 1870–'71, owing to the want of fuel, and no preparatory arrangements were made before any of the said suspensions of work. They lasted during a space ranging between three and ten weeks respectively.

"I did not touch the blast-furnace during any of the periods of stoppage referred to, the most prolonged of them occurring at a time when the thermometer registered 10° to 17° C., and yet when work was resumed the furnace did its work again with surprising regularity. On

the last occasion, however, I was obliged to raise up the tuyeres, in consequence of the thickening of the bottom stone.

"For the last two years, the furnace has been blown from one meter and fifty centimeters above the original level. It behaves admirably, producing as much as 50,000 kilograms in twenty-four hours. I cannot conceive of any blast-furnace constructed upon a different principle being capable of withstanding the effect of events such as those detailed above, and yet remaining fit for work. The blast-furnace I am describing has entered upon the eighth year of its existence, and the condition of its core is such, as yet, that one will readily admit the almost certainty of its lasting out double or three times the said number of years, considering that the bricks of the in-wall and of the boshes have, up to the present, lost nothing of their thickness. This may be easily verified, for all the bricks coming to the outer air may be examined at any moment. Their thickness may be unerringly ascertained by piercing the walls with a small pin-drill. The walls, be it borne in mind, are but weak, measuring no more than 2 feet thickness at the base, and 18 inches at the summit of the in-wall.

"This thickness they have not lost during an existence of eight years. Experience has shown, moreover, that, the core of the furnace being exposed to the air, the internal heat produces hardly any effect upon the bricks, either by dilation or contraction. Hearth, boshes, and in-wall were originally fastened together in the Neuss blast-furnace by means of flat iron binders occurring at the third course alternately.

"This precautionary measure appears superfluous. It is over four years ago since I have had the binders removed at the hearth and boshes, as well as at the in-wall, in part; for I perceived that they served no useful purpose, since the cooling down of the bricks prevents expansion altogether. Indeed, the furnace in the parts referred to is just the same as on the day of its erection.

"At Vienna, I have exhibited at the *Deutscher Pavillon für Bergbau, Hüttenwesen*, (No. 8635,) a model of this blast-furnace, in which I have shown the deductions made from an experience of the working, during a period of eight years, of the first blast furnace of its kind.

"The chief alterations introduced by way of improvement consist in a diminution of the stack to a very great extent, at that part of it which supports the in-wall; this diminution being accompanied, however, by so considerable a sloping away from the center toward the rise of the boshes, that the space around the hearth and the boshes has been still further enlarged, so that it may be considered as perfectly isolated.

"I have also introduced a peculiar description of closed hearth, which admits of ordinary working, as well as working with a closed hearth. I have been using this method for the last six years with the very best results. Its application is very simple indeed, and free from the objectionable features of other known methods, since the work of the bottom of the furnace can be performed, in case of need, without depending upon the mouth of a tuyere for running off the slag.

"The hearth is closed in by a cast-iron tymp placed in the usual position. This tymp-arch is cooled by a current of water passing through a coiled iron fixed in the cast iron.

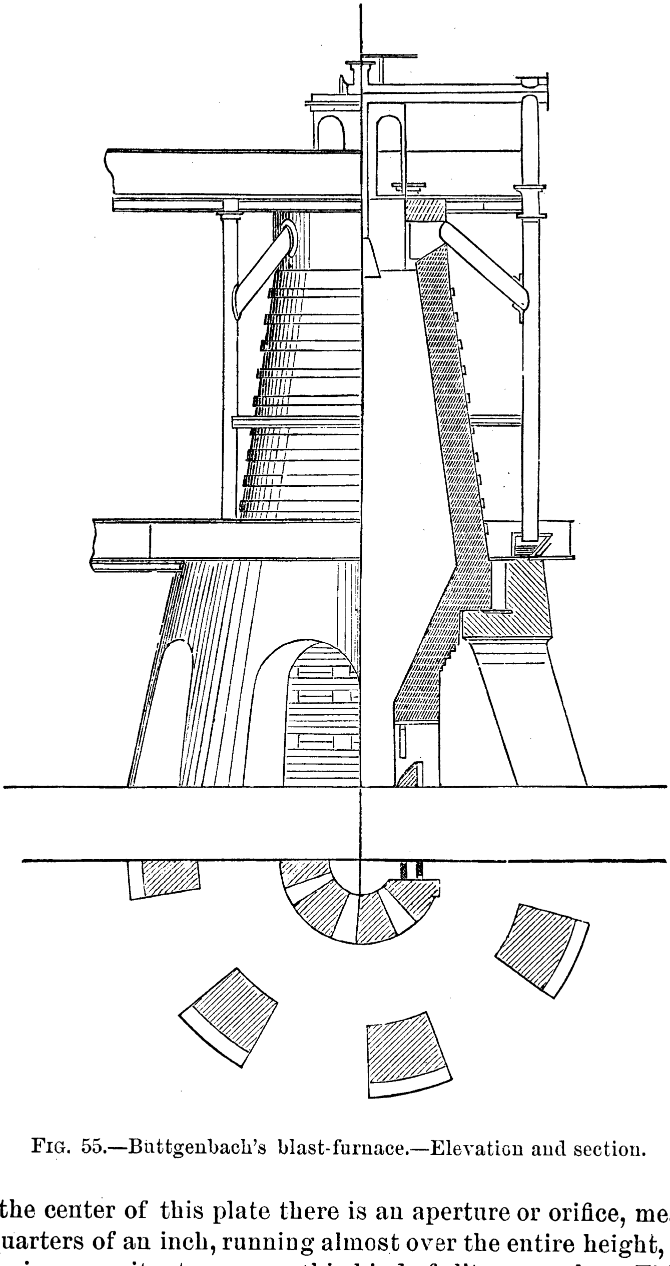


FIG. 55.—Büttgenbach's blast-furnace.—Elevation and section.

"In the center of this plate there is an aperture or orifice, measuring three-quarters of an inch, running almost over the entire height, and the cooling-pipes are situate as near this kind of slit as may be. This slit is closed up by means of ordinary clay. A, the upper portion of the slit,

is placed two or three inches higher than the center of the line of the tuyeres.

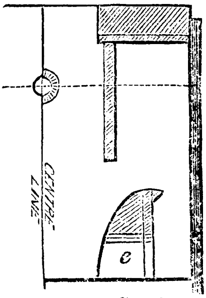


FIG. 56.—Section.

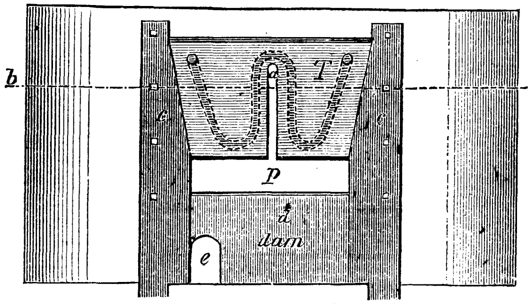


FIG. 57.—Front view of opening.

Front view.

"*b*, level center of the tuyeres; *c*, columns of the breast; *d*, dam; *e*, tap-hole; *p*, space between dam-stone; tymp closed in with clay; T, cast-iron tymp.

"The slag of the blast-furnace ascending above the dam-stone and reaching the level of the tuyeres runs off easily through a hole driven by means of a light steel bar into the said slit; and, since the level of this hole may be altered at will, a means is thus afforded for changing the level at which the slag is run off over a range of 24 inches, which is a very great advantage in itself; but, in addition to that, there is this further facility, namely, that nothing hinders one from tapping the melted ore at this same slit.

"I shall not dwell at length upon the advantages of such an arrangement, but will simply state that during the six years, since I have been making use of it, I have been unable to find any fault with it, and that in my practice it has always possessed all the advantages of the closed breast.

"In the said model, I have also applied three rows of tuyeres, made of gun-metal, overlying one another so that the upper row is two and one-half meters above the first. These tuyeres reach into the interior as deeply as the blast-tuyeres. By this arrangment the walls of the hearth are kept in perfect preservation, and in case of accident the blast may be introduced through the said tuyeres, affording advantages that iron-masters will be able to appreciate without further explanations.

"Practice has shown that this kind of blast-furnace, being readily accessible on all sides and at any moment, is far more easily managed than any other system; which fact practical men will readily admit.

"Over and above the advantages above enumerated, there is another, namely, that the construction of such a blast-furnace must evidently be, and is, in point of fact, much less costly than that of any furnace built upon another principle. It takes much less time to build, to dry, and to fire; in fact, it is a practical elucidation of your English proverb, 'time is money.'

"Let me add, too, that there is nothing to prevent the application of my system to blast-furnaces of all shapes and sizes, and that the largest section would just be the one best adapted for illustrating its great advantages, no less, speaking relatively, than its saving qualities.

"In conclusion, I must say that, to my mind, this system is the most advanced in simplicity of blast-furnace construction."

In reply to criticisms and objections made at the meeting and in the journals, Mr. Buttgenbach addressed a communication to Engineering, as follows:

"At the meeting of the Iron and Steel Institute I had the pleasure of reading a paper about my system of blast-furnaces—a system which was illustrated and described in your number of August 15 last; and I see with satisfaction that this paper is reproduced in your number of August 29, together with a report of the discussion. Your contemporary, *the Engineer*, has also published communications respecting my furnace, and in particular I notice an article in the number of that journal for September 12, expressing opinions adverse to my system. Allow me to say that I shall always be glad to find adversaries to my ideas, as their opposition only gives me occasion to explain these ideas more fully, and, I trust, in a more convincing manner.

"On the occasion of the discussion of my paper at Liége, it was impossible for me to answer thoroughly to the objections made by the members of the institute—first, for want of time, and, secondly, for want of sufficient knowledge of the English language. But having now the reports before me, and encouraged by the interest taken by the English press in my system, I think it due to those who have been present at the meeting, and to the readers of the papers, that I should reply to the various objections raised.

"1. To the objection offered by one speaker, that he did not consider the brick-work of the base practical, and that the use of cast-iron columns is to be preferred, I have to answer that this cannot be an objection to the system as such. I exhibited my model with a base of cast-iron pillars, and with a base of brick-work. My experience shows, however, that a base of red bricks is entirely sufficient, and leaves room enough round the blast-furnace to allow of even the most difficult repairs without opposing the slightest obstacle. I, for my part, would never allow a base to be made of cast-iron pillars, the cost of the latter being four or five times that of a brick-work or masonry base, and the last entirely fulfilling the desired purpose. The adoption of brick-work or cast iron for the base is therefore only a question of economy. The base of brick-work contains 100 cubic meters, while it costs at the Neusser Works only 1,300 francs, and could be constructed in fifteen days.

"2. A second objection raised was that a blast-furnace of the thickness of only one brick would not resist the pressure of the materials in large furnaces like those of Cleveland. I think that quite a false idea exists of this pressure. This pressure is not at all a great one, being

partly paralyzed by the state of the minerals, which, by the heat, are caused to adhere more or less together with the coke, without, however, being in a state of semi-fusion or vitrified.

"I have taken away a good part of the bricks of the stack, several meters above the largest section of a blast-furnace, but the mixture remained in the furnace and allowed me to replace the bricks I had taken away without the slightest difficulty. On this occasion I remarked that the bricks had not even lost 3 centimeters after a campaign of seven years.

"For the rest, as supporting what I have said above, I must state that an establishment which adopted my system made, contrary to my advice, the first blast-furnace with a base of cast-iron pillars, and after a few years' experience a second blast-furnace at the same works was constructed with a base of brick-work.

"3. Next, it has been asserted that there are in Cleveland and the North of England blast-furnaces with free-standing shafts.

"I have been over that part of England, and I have not seen *one* blast-furnace where the shaft had a thickness of only one brick; they have all inside a circle of large special bricks, surrounded by a mantle of brick-work, often thicker than the lining. In my furnace the single thickness of bricks is freely exposed to the air, and dilatation by heat being prevented, I am enabled to have a furnace without hoops.

"4. One opponent admits that my arrangement preserves the boshes against the attacks of the fire, but it is said that one could as well repair blast-furnaces such as those in Middlesbrough, which have a lining and a mantle round this of 3 feet or 4 feet thickness. I do not deny that repairs are possible in the latter case, but certainly they are expensive, very difficult, and require much time; every practical man knows that, as soon as one must go below, say 30 feet from the mouth, this becomes difficult work, the more so as the mantle hides the defects of the lining, and one does not know the state of the latter. With an entirely free shaft, on the other hand, one can perfectly well ascertain at any time the state of the bricks, and can easily make repairs, keeping the blast-furnace filled. I think this is a great advantage.

* * * * * *

"7. It was stated that scaffolding does not occur, or ought not to occur, with very hot blast, and especially not where Whitwell's apparatus is employed. I am an advocate of high-blast temperatures, and especially of Whitwell's excellent stoves, but it is not the great heat of the blast which prevents these scaffoldings; these depend upon the quality of the mineral and the coke of the district.

"I could name works in Luxembourg where the blast is heated by Whitwell's stoves, but where, with the small mineral to which I have referred, such dangerous scaffoldings have occurred in a new blast-furnace they feared they should be forced to blow it out. If at the crisis they had had tuyeres available 3 meters higher up, they could easily have got over the difficulty, the more as they had very hot blast.

"8. As to the way of conducting the gas, one must not forget that with mineral containing 20 per cent. of water, and of which two-thirds are small, (fine,) one has to take precautions quite different to those taken in Cleveland, where, though the ore is in lump, I have seen gas-pipes of 3 feet in diameter full of top dust, and which were cleaned with the utmost difficulty. All these difficulties disappear by my arrangement, and especially all explosions are without any effect—a very important matter when one has to do with wet minerals.

"*En résumé*, all the objections made concern the Middlesbrough district only, but out of this there exist others too; we, and many other works, work with mineral of which two-thirds pass into a sieve of 10 holes per square inch, containing 20 per cent. of water, and which cannot support any calcining, as getting too easily to powder. Under such circumstances, the Cleveland iron-masters would not have constructed blast-furnaces 85 to 90 feet in height, and would have had to take other precautions than they have to avoid stoppings every week, to manage the difficult cleaning of their gas-pipes, which would soon have been filled with dust.

"With materials as used in our district, where we use twenty different minerals always varying, and where coke contains as much as 18 per cent. of cinder, a blast-furnace cannot be so regular, or be so easily managed as a Middlesbrough, and there very often happen disturbances in the smelting process.

"The corrosive nature of the mineral containing manganese rapidly attacks the bricks of the blast-furnace, in consequence of which one makes everywhere preparations to prevent that, and I believe that the three series of tuyeres is the best preservative; for the rest, experience proves it.

"The Middlesboro blast-furnaces endure, it is said, ten to thirteen years, but certainly they would not do so under the conditions we have to meet here. My blast-furnace was erected in 1865, and its condition is still such that one will readily admit the almost certainty of its lasting out double or three times its present age.

"Altogether, I find that the observations made by the English iron-masters who condemn my system are too partial, the statements made reading as if the Cleveland district was the only district to be provided with furnaces, and as if the conditions which exist also existed everywhere. This, however, as I have shown, is very far from being the case.

"Even for the Cleveland district I think there are some advantages in my system which would be valuable; at least an eight years' experience of my furnace suggests this view to me. I may add, too, that seventeen of my furnaces have been constructed on the continent, and are all at work under almost entirely different conditions. I think this letter is a sufficient reply to the sharp criticism of the *Engineer* to which I do not want to reply in detail, not being disposed to enter into

polemics with a writer who makes inaccurate statements, and then founds arguments on them.

"I did not put up my system as a new invention in every particular of its arrangements, but as a total arrangement it is new. As such it has been acknowledged by authorities, including the owners of the seventeen blast-furnaces built on my system.

* * * * * * *

"NEUSSER IRON-WORKS, (near Dusseldorf,)

"*September* 16, 1873."

OSNABRÜCK IRON AND STEEL WORKS.

63. The Joint-Stock Company of Osnabrück, province of Hanover, founded in 1869, made for the first time an exhibition of its products for comparison with all others in the International Exhibition at Vienna in 1873.

Of the original grand plan of these works, only that part is now finished and this year in full operation which is intended for the production of Bessemer steel and its applications for steel rails, wheel-rims, axles, forgings, &c., and therefore the collection of objects on exhibition is naturally quite limited; but, on account of the origin and method of manufacture of these products, they are none the less worthy of examination.

The group of objects outside of the glass cases consists of—

1st. Bessemer-steel axles, of which three are rough-forged, and serve as a base for a group of wheel-tires; one is a finished forged, and one a finished turned, car-axle, and there is, moreover, one which was bent double in the cold.

2d. Bessemer-steel tires, of which one is finished; one is the rough forging for a tire, and is without a hole; the next one is rough but with a hole; six are rolled and finished, and of diameter from 480^{mm} to $2{,}420^{mm}$; and one was bent into the form of a figure 8 in the cold.

3d. Bessemer-steel rails, of which four pieces were bent into a spiral form, and one piece was twisted in the cold.

4th. Bessemer-steel forgings, among which are a piece showing the fracture, a large cylinder, two broken pieces of axles, five different proof-pieces from the ends of rails, and two forged ties.

Under the glass cover are—

5th. Various proof-pieces of Bessemer steel, among which is a hat with a tassel, made from the end of a tire.

6th. A collection showing the fractures of blocks of rough steel, forgings, tires, and rails.

7th. A rail-end and a number of sections.

8th. Breaking proofs of the products obtained by the use of different kinds of iron and coke.

9th. Samples of infusible clays and various infusible substances used

in the processes of manufacture of Bessemer steel, such as tuyeres, stoppers, funnels, &c.

The production, in tons, of the Osnabrück Iron and Steel Works has been as follows:

	1872.	First half of 1873.
Bessemer rough steel, in blocks	217.42	152.00
Finished rails	128.91	125.00
Tires, axles, and forgings	240.60	100.00

Average laboring force, in 1872, 850 men; first half of 1873, 1,000 men.

There have been employed a Bessemer plant, with two converters and five cupola-furnaces; 4 steam-hammers; a rolling-mill for rolling rails; a rolling-mill for tires; a machine-shop for turning axles; a foundery, with two cupola-furnaces and one flame-furnace; a forge, a carpenter-shop, a place for the manufacture of fire-brick, &c.

The thirteen heating-furnaces were heated with gas, which was generated in eight Siemens gas-furnaces.

Ten engines, together having 1,200 horse-power, were used as motors. The steam was furnished by 24 boilers.

A large and a small locomotive were used for transportation.

For some years previous Bessemer steel had been made almost exclusively from English hematite pig-iron, and although the German manufacturers had sometimes mixed with it a portion of German pig-iron, it was reserved for the Osnabrück Iron and Steel Works to make the finest Bessemer-steel products entirely from German materials, of which the neighboring *Georgs-Marien* furnace, with its iron rich in manganese, furnishes the larger part; and though from economical considerations the use of English pig-iron is not wholly dispensed with, it has been demonstrated that when the production of Bessemer pig-iron equals the demand, the continental manufacturers of Bessemer steel can dispense with foreign products.

The prejudice which has long existed against the employment of German materials for steel-manufacture, as well as the hesitation of the managers of railroads to employ Bessemer steel in the construction of roads, cars, &c., have both been overcome, and if Bessemer steel cannot be used in the manufacture of all other steel articles, its present improved quality allows it not only to be used for rails, but also to compete most successfully with crucible steel in the general manufacture of tires, axles, and other forgings, on account of its greater cheapness. Axles made entirely of German pig-iron have been tested by the royal directors of the Bergisch-Märkische Railroad, and have grandly withstood the very severe tests of falling weights.

The problem of making such a product from material the behavior of which in the different processes was uncertain was certainly a difficult one, but the managing engineer, Mr. Schemman, has by perseverance succeeded in overcoming all the obstacles and difficulties, after many unsuccessful experiments, and has solved the problem.

The converter-linings, the blast-pipes, and all other requisites made of fire-clay which are elsewhere used for the casting of steel, as well as the best of the imported furnace-linings, especially proved themselves to be of inferior quality, and only after all those and other requisites in improved quality were manufactured at the home works could the steel produced reach a perfection which will with difficulty be surpassed. The converter-linings which are made here have sometimes withstood 75 charges, and on an average 50 charges.

Tires of 2,420^{mm} diameter are made from a massive block of steel by punching a hole and rolling.

Rails, which are usually rolled 60 feet long, can, if necessary, be made 100 feet long.

The piece of a heavy shaft exhibited represents some which have been lately made for Westphalia, and which were forged with a fifteen-ton trip-hammer.

The adoption of new and improved machinery at the Osnabrück Steel Works, the fortunate location of the different departments of the works in relation to one another, the increased facilities for production on account of the additional buildings now in process of erection, the making of new products, such as rolling steel, spring-steel, sheet-steel, &c., in connection with the central location at the junction of three railroads, the proximity of furnaces and coal-mines, with property around the works already purchased for further enlargements, secure to these works a very successful future, and especially as local conditions allow cheaper living than is possible elsewhere, and therefore allow steel to be more economically produced.

GEORGS-MARIEN-HÜTTE COMPANY.

64. The Georgs-Marien Mining and Smelting Company, in addition to its very interesting exhibition of ores, iron, mining-maps, and sections of furnaces, published a very full description of the property of the company, and especially of the benevolent institutions founded for the benefit of the workmen. This brochure, in German,* has been freely drawn upon for the following information, translated from its pages.

The origin and development of the works.—The Georgs-Marien Mining and Metallurgical Company was organized in the year 1856, as a joint-stock company for mining iron-ore, coal, and other minerals, and also for the production of iron and other materials from them.

The capital stock is 2,500,000 thalers, of which 1,500,000 thalers were immediately expended, and 650,000 thalers more, making a total outlay of 2,150,000 thalers. Besides this, a loan of 700,000 thalers was contracted, but which is now being rapidly paid. The company bought, in 1856, the mining-privileges of their present property, "Heügel I," a bed

* *Beschreibung der Verhältnisse und Einrichtungen der Georgs-Marien-Hütte bei Osnabrück, Aussgestellt unter Gruppe I, Nro,* 8642. *auf der Internationalen Ausstellung in Wien im Jahre* 1873. *Osnabrück, Druck von J. G. Kisling,* 1873. 4to. Pp. 21. Plates.

of iron-ore, containing 4,815,500 square meters, at Beckerode, near Osnabrück, with the furnaces and machine-works that were upon it. The company also bought various other beds of clay and bog-iron ore in the county of Osnabrück, and received, in 1856, a grant of the coal and iron fields of Glückauf; in 1857, of those in Dörenberg, and in 1858, of those in Hilterberg. These fields together have an area of 48,220,000 square meters. Moreover, in 1865, the company received a grant of the iron-beds of Hügel II, with an area of 3,721,000 square meters.

The iron-ore beds Hügel I and Hügel II lie on the so-called Hügel, which is a mountain-ridge (one of the spurs of the Teutoburger forest) one and a half miles southwest from the city of Osnabrück. Brown and spathic iron-ores are chiefly obtained from them.

The coal-fields of Glückauf, Dörenberg, and Hilterberg lie in the forest clay-formation of the Osning Mountains, or the Burger Mountains, one and a half to two miles southeast of the city of Osnabrück.

It was the intention of the company to connect all their mines of coal and iron by a railroad running east and west, and then to establish at some suitable point extensive smelting-works, which should be independent of the precarious production of charcoal, and be supplied with coke. The location of these works was especially dependent upon a sufficient supply of running water, which was found in the valley of the Düte. The space for the location of the works was purchased from the government of Hanover.

The building of the works was rapidly carried forward, and in 1858 a coke-furnace was in operation. The transportation of the materials from the iron-ore fields at Hügel, and the coal fields at Oesede and Borgloh, was done at that time by horse-power on roads constructed by the company.

The great amount of water in the Düte Valley, and the insufficiency of the machinery for its control, made the working of the coal-mines peculiarly difficult and expensive. Coal could be obtained cheaper from Dortmund, and in 1866 the working of the coal-mines of the Düte was provisionally stopped. The same combination of circumstances worked against the other coal-mines, so that after due deliberation the plan of building a railroad between the works and the coal-mines was abandoned, and the construction of a railroad between the works and the mines at Hügel and the Westphalian collieries was taken up with vigor, and in 1870 railroad communication was established with the great thoroughfare of the Cöln-Mindener Railroad.

The construction of the Hamm-Osnabrück Railroad, which is now progressing, will connect the coal-mines of the company directly with all other points, and will enable the company to work them to advantage.

The company has now the sole management of the railroad between Oesede and Hasbergen, and also that from Domprobst and Sundern to Rothenberg, and uses upon these railroads five locomotives and hundreds of freight-cars, besides passenger-cars; and they use the same not

only for their own business, but do a steadily-growing general carrying-business.

The working of the little charcoal-furnace and rolling-mill at Beckerode has been suspended and superseded by coke-burning furnaces. The price of charcoal is constantly rising, while the quality of coke is rapidly improving, and therefore the company is able to produce a better quality of pig-iron at a much less cost than formerly.

The products of the Georgs-Marien Works have been principally sold to the steel, puddling, and rolling works of Westphalia for the manufacture of articles of the best quality. The iron competes favorably with the better kinds of pig-iron from Seigerland.

The rolling-mill and machine-works at Beckerode were too small and their sales too insignificant to justify their continuance. These works were therefore incorporated with the Georgs-Marien Works, which were then approaching completion; and the Beckerode shops were used for the construction of steam-boilers, mostly for home use, and in repairing machinery, using a small water-power as motor, while some of their workmen with their families lived in the house of the company at Beckerode or in the neighboring villages.

Although the Georgs-Marien Works have not yet reached their full development, either in their means or their production, in consequence of the imperfection of communication, yet the size and technical arrangements, the quality and quantity of their productions, and, not the least consideration, the number of workmen employed and the excellent accommodations for their welfare and happiness, give the works a right to claim a conspicuous place among their competitors.

The company owns, besides the already-mentioned railroads and equipments, 6 finished blast-furnaces, of which 5 are in blast, each having 3 hot blasts, each one of which has a heating-surface of 140 square meters, the apparatus being of a peculiar construction, made with hanging pipes. There are 14 crushing-machines and 5 horizontal blast-engines.

There are, besides these, various other stationary engines for different purposes, with 54 boilers of different construction, having together 3,700 square meters of heating-surface and 2,500 horse-power. The requisite coke is produced by 300 coke-furnaces, and the gas thus obtained is used as fuel for the boilers. A machine-shop and foundery are employed as an auxiliary to the works and the mines, for the manufacture of the tubes, ore-breakers, machines, &c., that are needed. The machine-shop has an engine and about 40 working machines, and all the apparatus necessary for the construction and repairing of engines and machines. Its annual production is estimated to be worth 130,000 thalers. The foundery has a blast-cylinder, 2 Irish cupola-furnaces capable of melting from 3,500 to 5,000 kilograms per hour, derricks, and all the accessory apparatus, and is capable of producing two million kilograms of castings per annum.

The blast-furnaces produced in 1872 53,118,100 kilograms of pig-iron, valued at 1,882,000 thaler; while in 1867 the production was but 32,473,890 kilograms, valued at 920,000 thaler.

It should be noted that of this production, in 1872, 70 per cent. was Bessemer pig, and 30 per cent. was a good quality for puddling, while, in 1867, 28 per cent. was Bessemer pig, and 72 per cent. was good puddling-iron.

By means of a peculiar contrivance connected with the blast-furnaces the greater part of the slag from them is granulated, and thus it is capable of being used for a variety of purposes, for example, as a packing around railroad-sleepers, in the manufacture of mortar, good bricks, &c.

A new contrivance, the invention of the director, Mr. Lüvmann, is of great value. The front hearth of the coking-furnaces is done away with, and the furnaces are tightly closed by a form made of slag and cooled with water.

The company is erecting gas-works, to make sufficient for 1,000 burners. It will be used in the works and the colony of laborers.

The raising and transportation of the ore is done by 7 stationary engines and 5 locomotives, run by 18 steam-boilers, having a heating-surface of 501 square meters, not counting 8 horse-power above and 4 horse-power under ground, in addition to that mentioned.

The quantity and value of ore raised at Hügel in 1867 and in 1872 were:

Year.	Ore, kilograms.	Value, thalers.
1867	160,722,000	69,964
1872	222,769,385	183,590

The whole works of the Georgs-Marien Company employ 1 general director, 1 metallurgical director, 1 mining director, 1 director of the machine-works, 35 men for overseers and office-service, and 1,600 workmen, distributed as follows:

At the blast-furnaces	450
At the foundery	80
At the machine-shop	140
On the railroad	80
Carpenters, builders, masons	110
Miners at Hügel I	650
Day laborers	90
	1,600

The company was awarded a medal at the International Exhibition at London in 1862, and in 1867 it received a silver medal at the exhibition in Paris, for the good quality of the pig-iron produced.

The prosperity of the works is shown by the dividends paid to the stockholders in the past four years, as follows: 1868–'69, 10 per cent.; 1869–'70, 10 per cent.; 1870–'71, 8 per cent.; 1871–'72, 16 per cent.

65. INSTITUTIONS AND ASSOCIATIONS FOR THE PHYSICAL AND MENTAL WELFARE OF THE WORKMEN AT GEORGS-MARIEN-HÜTTE.—The Georgs-Marien Joint-Stock Company differs very materially from most manufacturing companies in that it not only aims to give the shareholders the largest dividends possible, but besides its industrial purposes it seeks to promote the welfare of the working classes, by forming a community of them, and establishing and supporting for them churches, schools, clubs, associations, and other beneficial institutions. Deeming this the surest way of accomplishing its purposes, the company has made this work one of its first and chief efforts.

The company was obliged to create a new industry in a part of the country where the prospects for the future were good enough to justify considerable preparations and the attempt to benefit the poor laboring classes of the surrounding villages.

This was a great undertaking, for at the time of the founding of the works they were at the distance of a half an hour's ride from the larger country roads, and could only be reached by primitive lanes and byways, as was also the case with the small villages. Therefore roads had to be constructed to the newly-acquired coal-fields and iron-mines, while all the old roads had to be improved.

The inhabitants of the district were for the most part farmers, and for the few such as had spare time there were always chances enough for employment at the neighboring coal-fields. This had its advantages for them, since the laborers at the works would be obliged to devote all their time to it, while at the coal-mines the mining being done by shifts, working eight hours each, they had sufficient time to work their fields also. Under the existing circumstances most of the inhabitants of the district could not take steady employment at the new works, and even those who might have done so could only be prevailed upon by the offer of higher wages, and even then they were very slow to come and begin work for the "strangers." It was, therefore, an unavoidable necessity to engage laborers from remote parts of the country, and for whom in this very thinly-settled district habitations and boarding-facilities could not be found.

66. *Houses.*—Thus the company was forced at the outset, and before any technical work could be begun, to provide houses for their workmen, on a plan which of course could not satisfy all demands for comfortable living, but which would permit of the speediest completion and give shelter to as many as possible. These houses were built with a frame-work as general lodging-houses, but so that they might afterward be converted into dwellings by the erection of partitions. Nineteen of these houses were so built, and are known as "lodging-houses."

Afterward, as the number of steady and settled employés increased,

and there was more opportunity for deliberation and forethought in building, more regard could be given to the lasting comfort of the workingmen. Houses were built upon the same plan, for but two families, and so that each family had a separate entrance, shed, and yard. The disadvantages of these houses were the same as with the lodging-houses: slight frames, low ceilings, small windows, and insufficient ventilation. Then the sheds for stabling, &c., were so closely connected with the houses that they were unhealthy and not durable.

After finishing the above-described dwellings in 1859, the company decided not to enlarge the colony on this plan, believing that the workmen could be induced to take the matter into their own hands, and secure for themselves an independent homestead, and that the company would thereby secure a set of steady, interested laborers. To this end a building-plot of thirty square rods, at a standard price, and an advance of cash to aid in the erection of the proposed building, was offered to each workman. The workman had to pay 4 per cent. interest on this sum, and, moreover, allow the company to retain and apply such a proportion of his monthly earnings that the property would be unincumbered in the course of fifteen years.

The conditions for the granting of the loan were—

1st. That the plan of the proposed house should have the approval of the architect appointed by the company.

2d. That the building of the house should be under the supervision and control of the company's architect, in order to protect the builder against fraud, and in order that the company's money should be expended for this stated purpose only.

3d. That the laborer should himself furnish a part of the necessary capital.

This last clause was never fully enforced, and this was the first cause which led to the failure of this plan.

Very soon after the adoption of this plan a number of workmen made application to obtain the offered privilege and to build their own houses. In the course of building it would often be the case that enlargements would be made, and alterations of the original plan, which would demand a greater outlay than at first contemplated. Then the furnishing of the new house would cost much more than was expected. In almost every case the capital needed from the company exceeded the original demand. It resulted that the payment of the interest and the monthly deductions from the wages were too burdensome for many of the men, and, as a natural consequence, some of the houses were sold to third parties who were not interested in the success of the company, and thereby the good intentions of the latter were more or less frustrated.

To avoid these evils, the third clause was amended so as to read that the applicant for a lot and loan should possess at least a half of the needed capital. Under this condition it was thought that the builder would at least be more considerate in the use of his means; but the re-

sult of this experiment was the total suspension of building by the workmen, and the company was again forced to erect houses for their men, although much against its inclination. After due consideration, a new and well-approved plan was adopted, and upon it sixteen new dwellings were built as an experiment, and these having given entire satisfaction, the number will be increased in the course of this year by the addition of forty-four more.

The dwellings are judiciously separated from one another, as they also are from the sheds, yards, &c. The entrances to the houses are opposite each other; the rooms are high and airy. On the first floor are a sitting-room, bed-room, and kitchen; on the upper floor either one large chamber or two small ones. The cellar is large enough to hold the winter-stores, and is entered from the kitchen. The shed has two compartments—one for a pig and one for a goat, and room above for winter-fodder. A garden of from 15 to 20 square rods is connected with each dwelling.

The walls of the houses are made of the bricks made of slag, and a space of 2½ inches is left between the walls, rendering the dwellings perfectly dry.

The best evidence of the adaptation and desirableness of these dwellings to the workmen is furnished by the fact that it is looked upon as a reward and a special privilege to obtain one from the company.

The officers of the company, who originally had to live either in lodging-houses or other public places, are now also better provided for. Special buildings have been erected for them. These houses contain on the first floor five rooms and two chambers, and on the upper floor six more rooms. In the basement are the kitchen, pantry, and cellar room. In the rear are sheds similar to those of the laborers, with a garden-plot of about thirty square rods, for the cultivation of vegetables. The company owns now six houses for officers, and one so-called director's house.

Differing a little from the above-described family double dwellings are the houses for the foremen and lower officers of the works. They contain two sitting-rooms, two chambers, and basement. There are now four of these houses built, and four more in the course of erection, which will be finished this year. The possession by the company of so much fertile land enables them to lease to their workmen who desire it a plot of ground for farming, and this has proved to be a great advantage to them. It is a fact worthy of note that in this way eighty acres of rough land have been cleared and made suitable for cultivation, or converted into building-lots. The land is leased at a fixed price, and the different lots distributed by ballot among the workmen.

As has been already mentioned, the works are too distant from other communities to receive from them any of the benefits of social life. It was therefore necessary to organize an independent community, and to provide means for the solemnization of marriage, baptism, and death.

The now existing community was organized in 1860 under the name of "Georgs-Marien-Hütte."

It is evident that a united community can only exist as such when properly provided with all the requisite arrangements and necessary institutions for the bodily, mental, and moral welfare of its members, such as churches, schools, hospitals, and other associations.

67. *Schools at Georgs-Marien-Hütte.*—In January, 1857, the first evangelical private school was opened with 22 children, and at Easter, in 1862, the same was re-opened as a public school with two classes and 180 children. For this purpose an evangelical school society was formed, in which the inhabitants of the surrounding villages were received, whose children had, till that time, received their education in the existing Roman Catholic schools and their religious institutions in the city of Osnabrück, some five miles distant. There are, at present, some 280 children in the community schools, divided into four classes, under four good teachers. Another school, situated near the iron-mines at Rothenberg, has been established by the company.

The school-house building contains four large school-rooms, one confirmatory, three dwellings for married teachers, and one dwelling for an unmarried one, which can, when needed, be easily converted into another large school-room for a fifth class by taking down the partition. The southern part of the building was erected in 1864, and consisted of two large school-rooms, which, when the large double folding-doors were opened, were converted into one, and used for prayer-meetings. In 1868 the third class-room, and in 1869 the fourth class-room, were added.

The rapid growth of the school soon made the room too small, and provision had to be made for the increase of pupils by obtaining rooms in private houses, and it was only possible in 1872 to finish the northern part of the building and unite all classes under a single roof. For the accommodation of the Catholic members of the community, represented by about 60 children, the company established a temporary school in 1871. This house contains a large school-room, which is also used for divine worship, and also apartments for the teacher.

The directors of the company are the patrons of the evangelical school, and this gives them the privilege of nominating three teachers, the other being chosen by the state.

68. *Churches.*—As already stated, the rooms of the evangelical school-house, as well as of the Catholic, were constructed with the intention of using them provisionally for divine service. Although the need of a minister of the gospel was keenly felt by the members of the community, since the nearest place of worship was about five miles distant, it was not until 1867 that an evangelical, and until 1872 that a Roman, priest could be engaged, and the building of churches is now taken in hand by the respective congregations.

69. *Industrial schools.*—Near the elementary school there is a high or

advanced school for the older boys and the younger workmen. Instruction is given by the regular teachers, and by the engineers of the company, on every Monday, Tuesday, and Thursday evening; also, on Sunday mornings before church-time. Instruction is given in the following branches: German and English languages, technical and ornamental drawing, arithmetic, writing, physics, and cosmogony. The younger workmen during their apprenticeship are obliged to attend this school, which numbers, at present, about 30 pupils.

A girls' industrial school has also been established, where, under the guidance of a female teacher and some of the able housewives of the officials, the girls are instructed in knitting, sewing, and all other necessary handiwork.

Similar schools have been established also at the colony Rothenberg for young miners and girls, and they are well patronized.

70. *Libraries.*—Close by the schools stand the public libraries. They were founded in 1862, and contain now about 800 volumes, some of which are very valuable. The first and second teachers of the evangelical schools act as librarians. The books are in great demand by the workmen, especially during the long winter evenings.

71. *Court of justice.*—We cannot close this account of the institutions of the community without mentioning the peculiar court of justice which is one of the greatest blessings in the place.

The court of justice, or the peace society, strives for an adjustment of all controversies, without the intervention of the courts and the processes of the law. Members of this society are—

1st. All the employés of the company.

2d. All others who dwell on the company's grounds, and who have pledged themselves by signing the constitution and by-laws of the society.

For the settlement of all differences between the members, nine justices of the peace are chosen from among the members of the society, to serve for the term of one year. The meeting of this court is not held at definite, stated times, but whenever required, and the time of meeting is made known by public proclamation.

The members of the society are bound, in all differences between themselves, to call on this court before entering suit in any other court of law, or before denouncing one another. The parties must appear personally, and all counselors, except members of the family, are excluded.

This court of public peace was founded in 1865, and had in the beginning its hands full of minor cases of every kind and description, but the fact that its decisions were impartial and plain, and that the guilty parties had to submit generally to a severe rebuke in the presence of a great number of their friends and comrades, caused it to be feared even more than the courts of the state.

72. *The workingmen's association.*—This society is based upon the mutual-benefit plan. It secures to its members—

edical aid and care, free of expense in case of sickness.

2d. Compensation for wages lost during sickness, at the rate of one-half the regular wages, at the maximum of 12½ silbergroschen per day.

3d. A life-long pension to invalid members of from 20 to 50 per cent. of their ordinary wages, and even the whole amount of wages in exceptional cases; 25 thaler per month is the highest.

4th. One-third of the pension of a deceased member to his widow.

5th. Support and education for the children of deceased or invalid members until confirmation, (generally at the age of 14.) In exceptional cases support is given even till they have reached the age of 20 years.

6th. Assistance at burials; sometimes payment of the whole expense

The funds of the society are divided into three classes—1st. Sickness-fund; 2d. Pension-fund; and, 3d. Capital-fund.

Every workman has to contribute to the first class. They can contribute to the second class under certain conditions. All those who contribute to the first fund only are designated as "unsettled" workmen, while those who contribute to both funds are classified as "settled" workmen.

In 1872 the association numbered 1,535 members; "settled" members, 412; invalids, 2; widows, 13; children to be supported, 46.

There were spent in 1872:

	Thaler.
In cases of sickness	11, 115
Pensions	770
Exceptional support	112
Burial expenses	92
Society expenses and sundries	443
	12, 572
Income	20, 217
Surplus	7, 645

The cash capital of the association, exclusive of furniture, amounted to 39,063 thaler at the end of the year 1872.

73. *Hospital.*—For the care and treatment of the sick, a well-furnished hospital is provided. It is under the care of an excellent resident physician and nurses, and has a drug-store attached. The hospital was at first located in one of the lodging-houses, but now is in an independent building erected for the purpose by the company, and placed at the disposal of the "Workingmen's Association," free of charge.

For all technical establishments of this magnitude a hospital is indispensable, and especially is it important here; for the workmen are scattered over a large area, so that it would be very difficult, if not impossible, for the physician to pay the necessary attention to his patients in case of accident or severe sickness. In the year 1872 there were 3,345 cases of sickness, making an aggregate of 17,396 days of sickness, to which the physician would never have been able to attend were it not for the hospital.

The hospital-steward is the assistant to the physician, and he provides for the inmates at certain fixed rates of compensation. There are two nurses. Charges are made to the workmen according to their earnings, the company paying at the least one-half of all that paid by the workmen.

The administration of the affairs of the Workingmen's Association is under the control of—

1st. A board, consisting of four members, two of whom are chosen by the workmen, and the other two by the superintendent of the works.

2d. A certain number (at present four) of the older regular or settled workmen.

It may be regarded as strange that so small an amount has been paid from the relief-fund of the association for the aid of its members; but, besides this fund, there are several other funds from which, under the able administration of the board, large sums are given for the welfare and benefit of the workmen.

The principal of these funds is the "workingmen's deposit-fund," which was established by a donation of 4,000 thaler in 1866, and donations have been made most liberally by the stockholders, and were 2,827 thaler in amount in 1867; 6,502 in 1868; 6,775 in 1869; 5,830 in 1870; 10,979 in 1871; 6,823 in 1872. The accounts of the board which controls these funds are examined by a supervising committee appointed by the stockholders.

The other five funds are mostly for special purposes; one, for instance, for the education of the sons of workmen who prove able and worthy; one to give Christmas presents to poor children; one for extra support of orphans. All these funds are under the controlling supervision of the directors of the works.

Besides those organizations which, like the workingmen's association, are supported by fixed dues from the workmen who belong to them, and by donations from other interested parties, there are other very beneficial organizations which have been established by the administration of the works. One of these is the—

74. *Store-union.*—This is established for the purpose of enabling its members to obtain the necessaries of life of good quality and at reasonable prices, and thereby to enable them to lessen their daily expenses, and effect a saving. To this end contracts were made with different trading-houses and store-keepers, binding them to sell good articles at fixed prices, and at a certain percentage on the cost. The association has also opened stores itself, such as grocery, hardware, shoe, crockery-stores, &c. A bakery was established in 1872, and a butcher's stand is being started.

Every workman who will comply with the rules and regulations can become a member. All the goods bought at the stores of the association or of the traders under its control are paid for on delivery with tokens, which are afterward exchanged at the treasury of the company

for cash, and entered on the account of the buyer. The profits made by the stores in trade are divided among the members according to the amount of goods entered upon their pass-books. When this dividend is due they can draw the sum to their credit above three thaler at the treasury, or it can remain there bearing 5 per cent. interest, but the amount must not exceed 300 thaler, as this is the limit of capital of one individual in the store-union, allowed by the constitution.

This union is managed by a board of seven directors, four at least of whom are chosen from among the workingmen. As the store-buildings belong at present to the company, it supervises the affairs of the union, but the control will pass into the hands of the association as soon as the reserve-funds have accumulated to make a capital sufficiently large to warrant the independent maintenance of the association.

The following statement shows the amount of business done by the union: Capital deposited at the end of 1872, 15,549 thalers. Sales in this year, 17,768 thalers. Clear profits, 1,906 thalers, which, being divided among the members, after deducting the three thaler for the reserve fund, gave to each man a profit of 3½ silbergroschen to every thaler paid out in tokens.

75. *Lodging-houses.*—As beneficial to the bodily welfare of the workmen, the lodging-house is noticeable. It has been often necessary to engage large numbers of temporary workmen for the creation of extensive improvements, and at such times the want of places for lodging was strongly felt. The erection of barracks helped somewhat, but it was soon decided to furnish for this purpose permanent substantial buildings. The first buildings for this purpose were erected in 1870, one at the colony near Rothenberg iron-mines, and the other at the Georgs-Marien Works. The first-mentioned will soon be replaced by a larger one, but the latter has proved sufficient. Small rooms are provided for the accommodation of the young men, where they may occupy their leisure hours in study or literary pursuits without disturbance.

76. *Club-house.*—Quite recently it was thought possible to do something for the social needs of the workmen by building a club-house. This building is for the accommodation of the different societies and clubs; also for the meetings of the board of directors and other bodies. The building will also contain some apartments where the young, unmarried officers of the company can lodge. The smaller hall will accommodate the singing and orchestral societies, where their rehearsals can take place. The billiard and reading rooms are free to members of any society. A small hall is reserved for the meetings of different societies for culture or education, and is closed against all but members during the time of their meetings. About the building are grounds under cultivation for a park, free to all visitors. A walk of about fifteen minutes through this park leads to the shooting-gallery. A bowling-alley is near by the club-house, and is free to all visitors, save when any society is holding a sociable.

77. *The turn hall.*—This hall is nearly completed. It has a hall 13 meters long and 7 meters wide, used as a gymnasium. It has two rooms for the storage of turn apparatus, and a room for a fire-engine, hose, &c. The hall and the surrounding grounds are for the benefit of the scholars of the public schools and the Turners' Society.

The progress in the development of social life and habits has been very rapid. Already, in 1861, the first orchestral society was started by teachers, officers, and workmen. The society grew rapidly, and was well supported, though at one time it nearly succumbed. Rehearsals take place once a week, and every six or eight weeks a concert is given which is free to all members, and to their families and friends. The entertainment consists of orchestral music, solos, and singing. The directors of the company have recently engaged a musical director or leader, whose duties are to give instruction to the different musical societies free of charge. Encouraged by this, a brass band has been organized, which will eventually be the band of the colony. Especially worthy of note is the "*Liedertafel der Georgs-Marien-Hütte*," a singing-society which has, not only by its numbers, but by its very beneficial influence upon the morality of the community, a just claim to superiority. This society was founded in 1862, and has among its members almost the whole corps of officers and the majority of the members of the colony. One evening in the week is devoted to rehearsals, and every six or eight weeks a social gathering, enlivened by music, song, declamation, &c., is held. The society owns a large collection of written music, and a grand piano. A branch of this society formed exclusively of workmen devote their leisure hours to the cultivation of dramatic and oratorical talent, and by their successful representations they have materially assisted in the entertainments given by the other societies.

A rifle-club was established at the same time. It gathered about forty members, whopractice weekly, and once in each year they have a prize-shooting; and this custom is becoming very popular.

It was the opinion of the better-educated classes among the different societies that there was a lack of literary and scientific culture, and that something should be done for this object. Accordingly, a new society was formed in 1870, under the name "*Vereinigung*," (union,) with the understanding that all the members of the other societies could also join this without subjecting themselves to much expense. This "union" soon received such material aid from the directors of the works that they could offer free membership to all members of the other societies, and only outsiders are obliged to pay for admission.

In their weekly meetings, the political and social questions of the day, matters of interest to the works or colony, are discussed. A selection of periodicals is furnished for the free use of the members. It is proposed to connect with the union an improvement school for the older workmen, and to erect a building for the purpose, and also a savings-bank.

The union arranges for three or four so-called musical evenings in the course of the winter, in which the different musical societies participate, and in exceptional cases outside musicians of distinction.

The "*Turnverein*" has about forty members, mostly young workmen, who meet once or twice a week. By building a new hall for this society, it is thought that the additional facilities thus afforded will increase the number of members of this most useful society.

Among the societies of the officers of the works, there is a choir or singing-club.

Upon the establishment of the different societies, the board of directors granted certain amounts either as gifts or as temporary loans. Now the board appropriates a certain sum annually, granted unconditionally for the benefit of the societies, reserving for themselves only the right of placing a veto upon the appropriation of any money in cases where there is doubt of good intention in the appropriation.

This fund is controlled by the entire board of directors, which is composed of the directors of all the different societies, by which the requirements and wants of every society are duly considered and the money divided accordingly.

78. The following official statements are made regarding the hospital, the school, and dwelling-houses.

Hospital.—The hospital is arranged for 32 beds placed in four large halls, and four single rooms with one bed each. In addition, there is an isolated house with two rooms and a morgue. The ceilings of the hospital are 13 feet high throughout; the basement, built of freestone, with an arched brick ceiling, contains the kitchen-rooms, furnaces for heating, pantries, and cellar-rooms. Besides these, there are rooms for contagious diseases, and a vapor-bath. From the first floor upward, the walls of the hospital are constructed of porous brick made of slag, with air-chambers 2½ inches wide.

The slag-bricks are made of the granulated slags from the blast-furnaces, mixed with caustic lime, and the hardening of the bricks depends upon the presence of soluble silica in the slag, which, combining with the lime, gives the bricks great firmness. These slag-bricks have proved very useful at this settlement as building-material, and deserve the attention of the public in general, as being the best material for the construction of hospitals and sanitary buildings on account of their porosity. Though as yet the examination of the physical qualities of these bricks has not been made, there is no doubt but that they have a great advantage over ordinary building-stones on account of their porosity, but they must not be mistaken for the glassy slag-bricks which are produced at other furnaces.

The location of this hospital is excellent. It is free upon all sides to the sun and air; built upon dry ground, southwest in direction from the works, and thus protected from the smoke by the predominating western and southwestern winds. Near by is a small grove of beech-

woods and a small lake, through which a clear mountain-stream runs very rapidly.

The halls of the hospital are airy and light. There are no dark, close rooms. It is provided with pure water for washing and bathing from a high reservoir, into which the water is pumped by steam. The drinking-water is drawn from a well.

The principal corridor is 80 feet long, 7 feet wide, and 13 feet high, and has five windows. This hall opens into five rooms, containing in all twenty-two beds. Apartments of the same dimensions are upon the second floor. The hospital has, in addition, rooms for the physician, steward, and nurses.

The system of ventilation is that proposed by the architect, Scharrath. The principle is not to drive a large volume of heated air into the room through one or two openings, as is usual, but to distribute the heated air over the whole extent inside the walls, and admit it through small crevices in the walls, which at the same time have openings for the escape of the same quantity of foul air. The foul air is conducted away through a pipe, which is kept hot by the furnace or kitchen fires, and in summer by a special stove placed in the basement. It is the intention of the directors to increase the efficiency of this chimney by the use of steam-power, by directing a current of steam into the pipe in the summer-season. Extending lengthwise under the ceilings of the sick-room are square wooden boxes, which, after going through the whole length of the sick-room, enter the chimney. There are slits from 1 to 1½ inches wide along the box, which can be opened or shut. The advantages in this mode of ventilation are seen in the uniform distribution of heated air over a large area, thus avoiding all draughts, even when the apparatus is in its fullest activity. The heating-apparatus is in the basement, and consists of five stoves for heating the lower floor and two for heating the upper. The stoves are so constructed as to have a very large heating-surface. Thus the iron never becomes red-hot, the air is always pure and kept free from the disagreeable and unhealthy odors arising from the burning of particles of dust and other organic matters. The air in the three sick-rooms, where almost every bed is occupied, is always found to be odorless, sufficiently moist, uniform in its temperature, and entirely free from draughts, no draughts being observable either at the slits for the admission of heated air or for the exit of the foul. In room No. 1—which had eight beds and seven patients with fractured bones, very severe burns, and one who had both his legs amputated at the thighs—the healthful state of the patients and the condition of their wounds demonstrated that their treatment had been good, and that their favorable condition was in a great measure due to the good state of the atmosphere produced by the grand system of heating and ventilating of Dr. Scharrath.

School-houses.—The school-houses have in general been before described. Only a few additional remarks will be made. The two rooms for the

first and second classes are divided by folding doors, which are opened on Sundays to allow of divine worship. An organ with twelve stops has been presented by one of the former directors of the works. The building is built partly of sandstone and partly of slag-bricks. It is heated with stoves in the school-rooms, and the ventilation is produced by a stand-pipe, as in the hospital, but the ventilating-boxes, which in the hospital extend along under the ceiling, are here arranged around the walls at the height of the foot-boards, and thus they immediately carry away the cloud of dust raised by the many moving feet of the children. There are also large ventilators to serve to bring about a speedy ventilation at the intermissions. The corridors are used as play-rooms in rainy weather, while in fair weather the open space protected against cold winds by the structure of the building serves for the purpose.

The Catholic school, which is used at the same time as a church, is, though temporary, very suitable for the purpose, and includes a dwelling for the vicar and the teacher. The seats are benches with cross-backs; the desks have movable tops, but these are to be replaced by stools and good stationary desks. At the visit to the school-rooms, which took place directly after the dismission of the pupils, the air was found perfectly clear and free from dust, and at a temperature of 15° R., which shows the ventilation and heating to be perfect. On a visit to one of the older class-rooms, the air, though not found to be perfectly odorless, was yet not disagreeable, though 70 children had occupied the room without intermission for two hours.

Lodging and boarding house.—This is established with the view of affording the unmarried workmen the means of dwelling in healthy localities, and receiving good and wholesome food at a moderate price. The building is constructed on the same plan as the hospital, and of the same materials, has a very high basement for the culinary department. The cooking, for about 300 boarders, is done by steam. There are rooms for about 150 lodgers. The house contains two dining-rooms, each with 600 square feet of floor, and 24 feet high. They are heated by steam-pipes in the floor, and are ventilated like the hospital and school-house. The sleeping-rooms are in the two wings of the main building. In the rooms are iron bedsteads, one placed on top of the other, two by two, with mattresses and pillows stuffed with sea-weed; they are provided with linen sheets, and one woolen blanket in summer and two in winter. Between the beds are wardrobes, one for each lodger, and numbered to correspond with the numbers upon the bedsteads. They are 5 feet high, and are fitted with locks. The common wash-room contains 20 china wash-basins, and connected with this are the water-closets, which are closed during the day-time. In the eastern wing are smaller rooms, for from one to six lodgers each, who, of course, pay more according to accommodation. There are lodgings for from 40 to 50 men in this wing, while the western wing accommodates from 90 to 100 men.

The discipline of the house is in the hands of the steward, who is responsible for the observance of certain fixed rules and regulations established by the board of directors, who also at certain times inspect the victuals. The steward pays a yearly rent, for the use of the house and furniture, of 112 thaler. Board and lodging is paid for on the following scale of prices: Coffee and milk, 6 pfennig; dinner, with a quarter of a pound of meat or bacon, for a whole portion, 3 groschen; for a half-portion, 1¼ groschen; supper, without meat, 2 groschen. A boarder can procure boiling water for coffee or tea at any time free of charge, and every one procures his own bread and butter. Connected with this department, but in detached buildings, are a laundry, store-house, and bath-rooms with warm water, and for the use of which the steward collects a small fee. Near the steam-boiler is a disinfection-apparatus, into which steam can be admitted to free clothing, beds, &c., from vermin. All these rooms are well ventilated, and are always found unexceptionably clean and in perfect order.

The preceding statements show with what foresight and interest the managers of the Georgs-Marien Works care for the mental and physica welfare of their employés, and the success which they have achieved. Their action is worthy of all praise and imitation.

BOCHUM MINING AND STEEL WORKS.

79. The following list comprises the objects sent by this celebrated establishment, the *Bochumer Verein für Bergbau und Gusstahl-Fabrication, Bochum in Westfalen*:

(1.) Cast-steel propeller-screw in one piece, weighing 9,000 kilograms, about 9 tons. It is the first of its kind, and has not been forged in any part.

(2.) A cannon for a fort, of cast steel, with a bore of 21 centimeters, and about 10,000 kilograms in weight. The carriage upon which it is placed is from the manufactory of Gruson, in Buckbau, near Magdeburg.

(3.) A fort-cannon, of cast steel, of 15 centimeters bore, weighing 3,000 kilograms.

(4.) Two field-pieces, of cast steel, one 6-pounder and a 4-pounder.

(5.) A steam-cylinder for a hammer of 300 centners falling-weight, with the valve-box and base-plate all in one piece, made of crucible steel, weighing 7,000 kilograms. Near by it the piston and piston-rod, made of forged steel.

(6.) Press-cylinders of cast steel, the largest weighing 3,000 kilograms.

(7.) Cog-wheels of cast steel.

(8.) Steel pump-rod, 32 meters long and 165 milimeters in diameter, for a pump-rod, forged out of a block of cast steel. Weight, 5,500 kilograms.

(9.) A bent cast-steel cylinder for an elevator, 6,000 kilograms in weight.

(10.) A cast-steel bell of 1.83 meters diameter, weighing 2,850 kilograms.

(11.) A group, consisting of the different wheels for a locomotive, tender, and cars, part with cast-steel disk wheels, part wrought-iron spoke-wheels. Near by the last is the inner part of a wheel made of cast steel, three more made of wrought iron, and one of cast iron.

(12.) Different wheel-rims, bands, links, &c., of crucible and Bessemer steel, the greatest wheel-rim having an inner diameter of 3 meters.

(13.) *Herzstücke* of crucible steel of various construction.

(14.) A collection of springs, of various construction, made of crucible steel.

(15.) A collection of broken rails and wheel-rims, to show fracture, the samples taken at different stages of the manufacture, and the products made from different iron and iron-ore.

80. *The cast-steel works.*—The Bochum Company has been in existence for thirty years. For the first eighteen years it had but small capacity of production, and from that period to the present it has developed its great importance. The company's works and its mines cover an area of 140 hectares. The number of superintendents and minor officers employed is 250, and of workmen, nearly 6,000. The production of cast steel at the present time is about 11,000,000 pounds monthly. This product is worth nearly $700,000. In 1872 the production was 96,000,000 pounds, worth $6,000,000, gold value.

The raw material for the manufacture of cast steel is mainly obtained from the workings of the company, and the sources will be briefly noticed.

81. *The coal-mines.*—These mines, called the "Maria Anna" and "Steinbank," are situated at a distance of a half-mile from the steel-works. They are connected by railroad with the works, and at present are furnishing a part of the fuel required for the works from a single shaft. Two new shafts are being dug, and they will furnish 25,000 bushels daily to the steel-works and blast-furnaces next year. The mining-property embraces seven square fields, and possesses an uncommon richness of coal-beds. The coal is all of the best quality.

82. *The iron-mines*, in the Siegen and Nassau districts, are numerous and of great size, and furnish an important part of the ore used in the blast-furnaces of the company. Of particular value are the spathic ores mined near Kirchen. It is a superior ore for the manufacture of spiegel and Bessemer iron.

83. *Coke blast-furnaces.*—Two of ordinary size are in operation near Mühlheim, while two more of larger size are being built at Bochum, and two more are going to be built next year, and two more in 1875.

84. *The coke-furnaces* in Mülheim furnish coke for both of the blast-furnaces. Near the steel-works in Bochum are a large number of

coke-furnaces, part in operation, and a part in process of manufacture. Both the establishments at Bochum and at Mülheim economize the gas that is produced.

85. *The steel-works* at Bochum manufacture crucible and Bessemer steel. Thirty-six steam-hammers, from the smallest to the largest size, are used in forging the steel.

The Bessemer plant runs 7 converters, principally producing material for rails and blooms to be forged into tires and axles. The Bessemer steel and crucible steel for the manufacture of tires is made into blooms of sufficient size to make from ten to twelve tires, and then is cut up into pieces of proper weight, forged, punched, and rolled out, without being reheated in a heating-furnace.

One of the special operations in the works is the casting of steel in molds, after the invention of the technical director of the works, Mr. Jacob Mayer. The importance of the invention was acknowledged by the bestowal of the great gold medal of honor at Paris in 1855. Although the process was not patented in the country, it remained for ten years the exclusive property of the company and of those works in France and England which had obtained the patent-right. The great screw for a steamship, which was made for one of the ocean-steamers, having a diameter of 5⅓ meters, (17½ English feet,) as well as other heavy pieces, such as the press-cylinder and the cast-steel bell, with their sharply-defined coats of arms and inscriptions, show the significant progress of the Bochum cast-steel works.

The cannons exhibited show the favorable condition of this department. The first one, with a bore of 21 centimeters, was tested with five hundred shots to prove its durability, and fifty shots to prove its strength, by the imperial commission. The testimony of the commission and inspection of the piece both show that the piece has undergone no noticeable change in diameter or shape of the bore. The range of the piece with ordinary charge is 8,000 meters, which is more than a German mile.

The other pieces were also subjected to the most trying proofs, and show no change, either in the bore or the straightness of the piece. With these pieces are seen some missiles, some of which are new and some of which have been fired. The crucible steel for cannons is made according to a rule peculiar to the Bochum works, and patented by them. The steel is not brittle, and is characterized by its toughness and homogeneous nature.

86. Another specialty of these works is the manufacture of cast-steel bells. We have not space to detail all the advantages and virtues of cast-steel bells. The manufacture of these bells dates from the year 1851. As early as 1855, at the Paris Exposition, the bells of the company attracted general attention. The surprise of the inspectors at this new cast-steel product, indeed, the doubt as to the possibility of working steel in this way, was so great that they desired an inquiry to be made, to ascertain whether these bells were really steel, as was represented, or whether they were made of cast iron.

The result of this inquiry was the bestowal of the great gold medal by the jury of the exposition, upon the following grounds:

"The exhibited bells are characterized by perfection of performance, and a very clear, unmixed tone, which is as clear as that of the best ordinary bronze bells."

As a consequence, the jury came to the conclusion—

"That the Bochum Company, by its method of melting and pouring steel, have not only superseded bronze as the material for bells, but have given a new direction to the manufacture of large forged and rolled pieces for machinery."

The far-seeing decision of the French jury has received a brilliant confirmation by this year's exhibition. It was not only a great advance in theoretical knowledge, with but little development by practice, which awakened the surprise of the jury, for that which they characterize as "perfection of performance" is not only "*progress*" but a "*great progress realized.*"

These bells are cheap, costing only half as much as bronze bells; they are heavy, and, since 1855, their manufacture has very greatly and rapidly increased.

In the year 1858, a test proved "that it is impossible with human power to crack one of these steel bells with heavy sledge-hammers." In the practical use which has been made of them since the beginning of their manufacture, they seem to far outlast the bronze bells.

During the first seventeen years, the number of church-bells that were made was about 1,000, and about 1,500 of smaller kinds. In the last four years about 600 church-bells and 1,500 smaller bells have been made of cast steel.

The Bochum bells are widely distributed over the whole of Europe, though the distribution is somewhat limited by the fact that they are manufactured both in England and in France under patent-rights granted by the Bochum works. Besides the great number that are suspended in Europe, six have been sent to Asia, ten to Africa, forty-five to North America, and five to South America. Most of those to whom they have been sent have written, showing their perfect satisfaction.

The following is a price-list of the works:

A bell weighing 100 kilograms, 20 silbergroschen per kilogram.

A bell weighing from 100 to 150 kilograms, 18 silbergroschen per kilogram.

A bell weighing from 150 to 15,000 kilograms, 16 silbergroschen per kilogram.

In the good service that their bells have rendered, the company has sufficient guarantee that their cast-steel bells will not crack, and they moreover offer to buy back any bells that shall crack in the future, at half the price of the new ware. However, up to the present time, the cracking of one of the church-bells is unknown. The smaller kinds (such as are used for locomotives, for example) are the only ones which have ever been known to break.

87. *Extent of the Bochum works.*—For transportation within the cast-steel works, 6 locomotives, 100 cars, and 60 horses are used. Steam-engines, together of 7,500 horse-power, with 150 steam-boilers and a very large hydraulic power, are employed for driving the works.

The steel-works have in and near Bochum, 16 puddling-furnaces, 8 heating-furnaces, 92 annealing and warming furnaces, 27 cupola and reverberatory furnaces, 121 steel-melting furnaces, 135 forging and welding fires, 44 furnaces for heating air, 24 crucible, tube, and brick burning-furnaces.

There are 2 blast-furnaces now building, and 4 projected, which will soon be completed. Each of these six is capable of producing from 120,000 to 130,000 pounds of pig-iron daily.

In addition, there are 80 cranes, with and without steam-power; 4 crucible and brick presses, 5 clay-mixing machines, 21 grindstones, and 300 working machines of various kinds.

Also, 36 steam-hammers, the heaviest 600 centners falling-weight; and one of 1,200 centners is being set up.

The monthly production of railroad-stock is as follows: 1,000 combinations (2 wheels and 1 axle) of car-wheels; 40 full sets of wheels for a locomotive and tender, with the appurtenances; 2,000 car and 350 locomotive axles; 6,000 springs for locomotives and cars; 10,000 spiral springs for locomotives and cars; 16,000 to 18,000 rails; 200 to 300 *Herzstücke;* 150 to 200 *Gehobelte Weichenzungen.*

88. *Aid for the workmen.*—An institution, in the form of a joint-stock company, has been established which has for its object the building of cheaper and better dwellings for the workmen and employés of the company, the obtaining and the production of the necessaries of life, the care of the old workmen and the support of their families. The capital of the institution amounts to 1,500,000 thalers, of which 300,000 were received from the Bochum Company, 200,000 from the workmen and the former employés of the company, and 1,000,000 thalers is a loan. After deducting the large interest, (at 2 per cent.,) the remaining sum is devoted to the above-designated objects.

GLEIWITZ FURNACE, UPPER SILESIA.

89. The *Hochofen zu Gleiwitz in Oberschlesin* Company makes a most instructive exhibition of the progressive changes in the form, size, and production of their furnaces at different periods since 1799. There are four large drawings of equal scale, 1 to 10, giving sections of the furnaces in 1799, 1829, 1854, and 1872, showing in a vivid and impressive manner the gradually-increasing size and production. The data taken from these drawings are herewith tabulated.

Table showing dimensions and production of Gleiwitz blast-furnaces at four different periods.

Dimensions, number of tuyeres, and production.	Year.			
	1799.	1829.	1854.	1872.
Dimensions of furnace:				
Height .... meters..	11.18	13.14	15.04	13.04
Diameter at top .... meters..	0.96	1.36	1.88	3.92
Diameter at boshes .... meters..	3.45	3.14	4.79	5.34
Diameter at or above tuyeres .... meters..	0.94	0.63	0.94	2.56
Capacity .... cubic meters..	....	48.14	117.58	220.70
Tuyeres .... number..	2	2	3	8
Weekly production .... kilograms..	13,700	25,000	56,250	250,000

CHAPTER III.

FRANCE.

EXHIBITION BY THE SCHNEIDERS, CREUZOT; ATTRACTIVE INSTALLATION; THE ORES AND METALS USED; MANGAN-IRON; EXTENT OF THE WORKS; CLASSIFICATION OF IRON AND STEEL; TABLE OF THE PHYSICAL PROPERTIES OF SEVEN TYPES OF IRON MADE AT CREUZOT; COMMERCIAL STEEL AND ITS PHYSICAL PROPERTIES, AS CLAIMED AT CREUZOT; QUALITY OF RAILS; PRICES ACCORDING TO QUALITY AND HARDNESS; LARGE CASTINGS FOR LINING MINING-SHAFTS; REVOLLIER BIETRIX & CO. AND OTHER EXHIBITORS; ALGERIAN ORES.

90. The exhibitors of the iron and steel products of France did not enjoy the advantages of a separate building for the reception of objects pertaining to the mining and metallurgical groups, and consequently their exhibits were distributed in the Machinery Hall and parts of the main building, and were not so readily found as those of Germany and Austria.

The iron and steel production of France is shown by the annexed tabular statement from the years 1859 to 1874, inclusive:*

Years.	Cast iron.	Wrought iron.	Steel.	Total.
	Tons.	*Tons.*	*Tons.*	*Tons.*
1859	758, 682	531, 769	16, 922	1, 307, 373
1860	797, 932	503, 229	21, 244	1, 321, 605
1861	829, 481	591, 772	26, 169	1, 447, 422
1862	928, 574	648, 395	30, 490	1, 507, 459
1863	933, 907	707, 785	25, 372	1, 667, 064
1864	1, 034, 161	750, 881	28, 189	1, 813, 231
1865	989, 972	676, 775	31, 816	1, 698, 563
1866	992, 710	759, 142	28, 286	1, 780, 138
1867	931, 906	704, 160	36, 855	1, 672, 921
1868	934, 868	718, 272	66, 320	1, 719, 460
1869	1, 018, 899	801, 201	97, 284	1, 917, 384
1870	923, 842	617, 834	83, 788	1, 625, 464
1871	859, 641	635, 876	79, 811	1, 575, 328
1872	1, 217, 838	884, 203	130, 088	2, 232, 129
1873	1, 366, 715	889, 891	155, 568	2, 412, 174
1874	1, 423, 307	862, 254	217, 072	2, 502, 633

*From the *Bulletin du Comité des Forges de France*, cited by David Forbes.

Production of cast iron in France during the year 1874.*

Districts.	Foundery iron.	Forge iron.	Total
	Metrical tons.	*Metrical tons.*	*Metrical tons.*
Ardennes	4, 211	15, 549	19, 761
Paris Basin	....	....	....
Brittany	12, 073	2, 260	14, 334
Centre	52, 167	293, 082	345, 249
Champagne	76, 232	84, 976	161, 209
Comté	5, 987	45, 296	51, 284
Escaut	28, 676	73, 707	102, 383
Garde, Bouches du Rhône, and Corsica	21, 094	85, 896	106, 991
Loire et Savoie	29, 534	262, 882	292, 416
Longwy	37, 119	39, 919	77, 039
Meurthe and Moselle	24, 908	124, 977	149, 885
Sambre	9, 198	59, 874	69, 072
Sud-Ouest	2, 968	13, 811	16, 780
Usines d'Aubin et de la marine nationale	....	16, 900	16, 900
Total	304, 172	1, 119, 135	1, 423, 307
Total in 1873	252, 840	1, 129, 117	1, 381, 970
Increase in 1874	51, 332	....	41, 349
Decrease in 1874	....	9, 992	....

Production of wrought iron in France during the year 1874*.

Districts.	Bars, &c.	Rails.	Plates.	Total.
	Metrical tons.	*Metrical tons.*	*Metrical tons.*	*Metrical tons.*
Ardennes	34, 999	....	13, 944	48, 874
Paris Basin	40, 529	....	12, 077	52, 607
Brittany	7, 482	....	2, 869	10, 351
Centre	116, 043	40, 139	30, 439	186, 621
Champagne	93, 695	....	5, 111	98, 806
Comté	38, 001	4, 070	10, 766	52, 839
Escaut	50, 493	9, 092	7, 069	66, 654
Garde, Bouches du Rhône et Corsica	18, 639	6, 739	....	25, 387
Loire et Savoie	101, 563	16, 676	13, 570	131, 809
Longwy	6, 279	....	....	6, 297
Meurthe et Moselle	16, 990	....	....	16, 990
Sambre	59, 336	52, 945	13, 281	125, 563
Sud-Ouest	8, 386	....	....	8, 386
Usines d'Aubin at de la marine nationale	1, 598	28, 400	1, 075	31, 073
Total	593, 987	158, 063	110, 204	862, 254
Total in 1873	624, 772	151, 346	130, 626	906, 745
Increase in 1874	....	6, 716	....	....
Decrease in 1874	30, 785	....	20, 421	44, 491

Production of steel in France during 1874.*

District.	Bessemer and Martin.			Cast and puddled.			Grand total, metrical tons.
	Rails.	Bar, plate, &c.	Total.	Rails.	Bar, plate, &c.	Total.	
Paris Basin	....	360	360	....	250	250	610
Centre	62, 824	8, 729	71, 554	5, 600	....	5, 600	77, 154
Garde, Bouches du Rhône et Corsica	....	925	925	....	1, 235	1, 235	2, 160
Loire et Savoie	87, 222	39, 910	127, 141	....	9, 309	9, 309	135, 450
Sud-Ouest	....	672	672	....	....	....	672
Ardennes	....	....	....	....	23	23	23
Total	150, 047	50, 598	200, 653	5, 600	10, 818	16, 418	217, 072

**Bulletin du Comité des Forges de France*, February, 1875, cited by David Forbes.

THE CREUZOT WORKS.

91. Messrs. Schneider & Co., proprietors of coal-mines, iron-works, steel-works, and mechanical works at Le Creuzot (Saône-et-Loire) make one of the most perfect and ornate displays in the whole exhibition. It is in the machinery hall fronting the main passage-way dividing the English from the French section. It is compact but comprehensive. The ores from Algeria, Elba, and France, with the coals, coke, fluxes, and the direct products, are systematically shown. Then follow polished sections of all the forms of bar and angle iron, with samples of each bent and broken to show the quality. There is a similar series of steel-products, including sections of all the forms of rails made for various railways. The numerous specimens of great tenacity are particularly interesting. They comprise steel bars, 3 or 4 inches square, bent double; polished railway-axles folded back one end upon the other, and the journals bent at right angles, without, in either case, showing a crack or a flaw. This establishment is being rapidly extended in size, and, when the additions now in progress are completed, will cover 771 acres. The annual production of pig-iron is 180,000 tons; of wrought iron 90,000, and of steel 60,000 tons; number of workmen, 15,500. Experiments are being made to test the strength of the different brands of iron and of steel sold in commerce. Thousands of samples have been carefully tested and the results recorded. A classification based upon these results is proposed, which is said to have received the sanction of the trade. Seven degrees or classes of iron-ore are recognized, and the physical properties of each class are tabulated. For steel three classes are proposed, and these classes are to be designated by the letters A, B, C. A is to represent the ordinary grades, C the superior, and B the intermediate qualities.

92. As an example of successful and attractive installation, this exhibit is worthy of special note. The arrangement of the objects is accurately shown by the annexed ground-plan diagram.

93. *The show-cases* are lined with dark maroon-colored velvet, and the wood is finished in imitation of ebony. The glass is the finest French plate. Great care has been bestowed upon the labels, and in mounting the maps and drawings. In the show-case No. 3 we find the mineral fuels from the mines belonging to Creüzot as follows: Creuzot, Montchanin-Longpendu, Decize, Montaud, and from Brassac and Beaubrun mines, in which Creuzot is a joint owner. There is also a representation of the coke made at Creuzot from a mixture of bituminous coal of St. Etienne and washed coal-slack.

Ores.—Under the head of ores and metals used at Creuzot, we find in case 4 magnetic iron-ore from Mokta-el-Hadid, Algiers, province of Bona; oligiste iron from the island of Elba; spathic iron from Maurienne, Savoy; pisolitic ore from Berry, Chanteloup, Saint-Florent, Cher; oolitic ore from Mazenay, Saône-et-Loire; limestone-marble from Gilly, Allier.

(5.) *Pig-iron* fo r refining, for foundery purposes and for the manufacture of steel, classified according to quality and appliances. Furnace-slag of the same. Some mangan-iron of high percentage, claimed to contain 70 per cent. of manganese, was shown. This is made by adding manganese ore to a bath of molten iron in the presence of charcoal in a Siemens furnace.

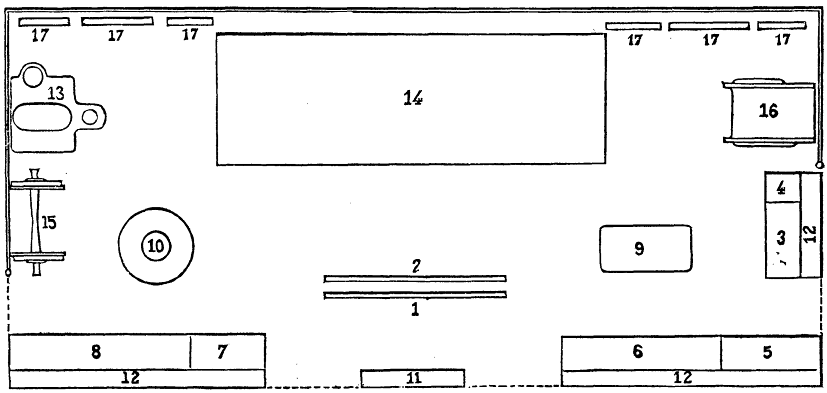


FIG. 58.—Plan of Creuzot exhibition—general arrangement.

1.) Picturesque view of Creuzot.
(2.) Geometrical plan of Creuzot.
(3.) Coal show-case.
(4.) Minerals.
(5.) Pig-iron.
(6.) Wrought iron.
(7 and 8.) Steel.
(9.) Appliances of the iron.
(10.) Appliances of the steel.
(11.) Fractures of iron and steel.
(12.) Rolled profiles of pieces of iron and steel.
(13.) Engine of 20 horse-power.
(14.) Locomotive, Midi Railway.
(15.) Wheels, axles, and tires.
(1) Cylinder of marine engine.
(17.) Drawings of bridges.

(6.) *Wrought iron* classified by numbers of quality, from 1 to 7. Tested bars showing the respective physical properties of each quality.

(7 and 8.) *Steel* classified by numbers of hardness, from 1 to 11, and by marks of quality, A, B, C.

(9.) *Specimens* showing the quality of the iron, classified according to the numbers, worked up either cold or hot, and different appliances.

(10.) *Specimens* showing the quality of the steel, classified according to the numbers, worked up either cold or hot, and different appliances.

(11.) *Fractures* of rails and other pieces of iron and steel, showing the texture of the metal.

(12.) *Profiles* (cross-sections polished) representing the rails and merchant iron made by the Creuzot Iron-Works.

This establishment manufactures engines and locomotives, and they exhibit, upon the space marked in the plan 13, an engine for workshops,

with vertical cylinders on frames; high and low pressure, with condensation; 20 nominal horse-power; patent governor.

In the center space, marked 14, a highly-finished freight-engine for steep gradients, for the Midi Railway Company; eight wheels coupled; outside cylinders. Weight of engine empty, 47 tons 8 hundred-weight. This locomotive is one of twenty made to order by the works in 1872.

(15.) Upon this space *railway-wheels and axles* are shown in a highly-finished state. Both axles and tires are of Creuzot steel. Axles and tires of the same pattern and finish are shown folded up and bent in opposite directions without exhibiting a flaw.

(16.) Upon space 16, opposite the steam-engine, they exhibit a *steam-engine cylinder*, rough from the foundery, as cast for the paddle-engines, with high and low pressure, of 350 horse-power, of the steamer Petrel, of the French navy. This piece weighs seven tons. The diameter of the high-pressure cylinder is 3 feet $1\frac{15}{16}$ inches, and of the low-pressure, 5 feet $1\frac{5}{8}$ inches; stroke of pistons, 3 feet $3\frac{1}{2}$ inches.

(17.) In the spaces marked 17 there are several *models, plans, and drawings* of public works, bridges, viaducts, aqueducts, &c., among them a drawing of the bridge of Friburg, on the railway from Lausanne to Friburg, 1859, of which the iron-work weighs 3,000 tons; the swing-bridge of Brest, 1860, weight of iron-work 1,170 tons; the bridge on El Cinca, Spain, 1866, weight of iron-work 247 tons.

Drawing of the bridge on the Chiffa, Algiers, 1868; weight of iron-work 419 tons.

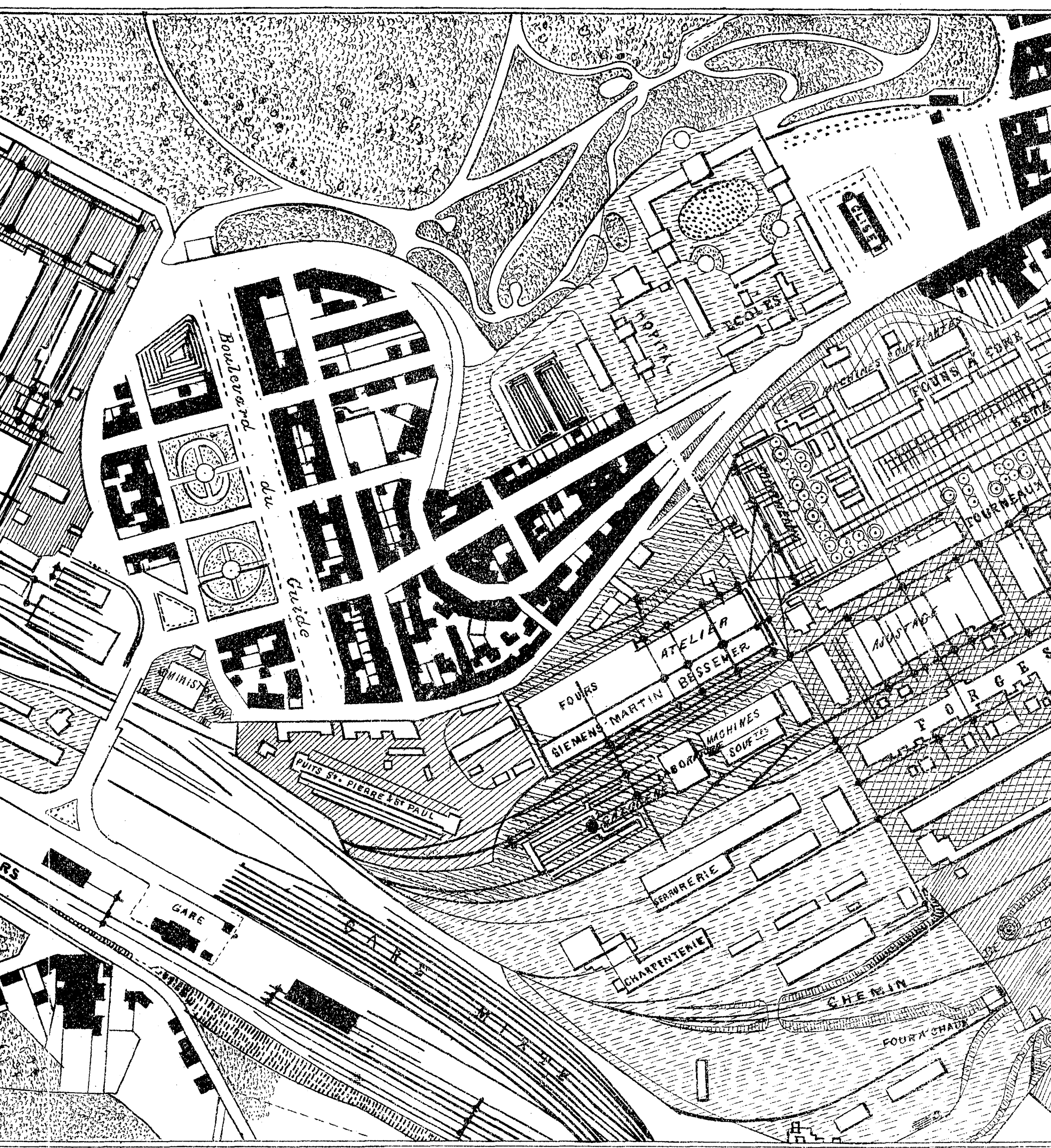
Drawing of the bridge on the Danube, at Stadlau, near Vienna, constructed at Creuzot in 1869 for the I. R. P. Company of State Railways, scale $\frac{1}{400}$. Distance between abutments, 1,264 feet 8 inches; number of columns, 4; distance between centers of columns, 263 feet 2 inches; weight of iron-work, 2,140 tons.

There is also a diagram showing the manner in which the bridge has been put into its place by hauling.

Drawing of the bridge on the Danube, at Vienna, constructed at Creuzot in 1873 for the administration of the public-works department, scale $\frac{1}{400}$. Distance between abutments, 1,088 feet; number of columns, 3; distance between centers of columns, 275 feet 6 inches; weight of iron-work, 2,400 tons.

94. PRODUCTION.—The exact statistics of the works, as regards extent and production for 1873–'74, are as follows:

ITION. 1873.



Scale 1 to 5,000 or 1 m m for 5 metres.

0m 50m 100m 200m 300m 400m 500 metres.

Statistics of Le Creuzot, 1873–'74.

Statistical elements.	Creuzot.	Appendages.	Total.
THE WORKS consist of—			
Surface of the works and of the industrial appendages..	435	336	771 acres.
Surface of the buildings..................................	51	17	68 acres.
Length of railways, broad gauge........................	35	14	49 miles.
narrow gauge....................	18	62	80 miles.
Number of workmen......................................	9,800	5,700	15,500 workmen.
Number of steam-engines...............................	234	74	308 engines.
Horse-power of the same................................	15,700	3,300	19,000 horse-power.
PRODUCTION.			
Weight of coals..	190,000	525,000	715,000 tons.
Weight of pig-iron.......................................	180,000	....	180,000 tons.
Weight of wrought iron.................................	90,000	....	90,000 tons.
Weight of steel...	60,000	....	60,000 tons.
Value of locomotive-engines, (100 a year)..............	280,000	....	280,000 pounds.
Value of other machinery and bridges..................	240,000	100,000	340,000 pounds.

NOTE.—The extensions of the works at present in progress, and which are to be completed in 1873–'74 are taken into account in these statistics.

95. AWARDS IN 1867.—At the Paris Exposition in 1867 a grand prize was given for the raw and finished products of mineral industry, (Group V, class 40,) and another grand prize for mining-tools and processes of working the mines, (Group VI, class 47.) A gold medal for railway-material; a gold medal for civil engineering; a gold medal for materials for naval architecture and saving of life; a gold medal for methods of teaching children and apparatus for the same, and also a bronze medal to M. Nolet, as co-operator, for apparatus for the instruction of adults.

96. CLASSIFICATION OF IRON AND STEEL, CREUZOT.—The classification before mentioned is based upon the needs of the consumer, the endeavor being made to meet in a uniform and reliable way the demand already existing for iron and steel of certain qualities. In the notes and descriptions which follow upon this subject free use has been made of the valuable notes, in French, furnished by the firm.

When Messrs. Schneider & Co. decided to greatly extend their metallurgical works, they necessarily became solicitous that the outlets for their products should also be extended. To attain this end, the surest means was to seek to satisfy all the wants of the consumer in respect of quality as well as of form, or, in brief, to put into the market the equivalents of the principal varieties of iron in common demand. Their first step was to procure a certain number of bars of the same specimen of the brands best known in France, England, Belgium, and in all producing countries. These bars were submitted to mechanical tests when cold and when hot. From the data obtained from thousands of experiments in this way, the coefficients of strength were deduced, representing the relative value of each variety. It was found that the almost infinite varieties of quality produced by metallurgy could be grouped in seven chief divisions, and that these seven groups or types would satisfy all the needs of trade and the consumer. It then remained to find the means of realizing in practice the manufacture in the large way of these seven types of iron with uniformity and regularity.

Chemical analysis of both the irons and the ores was resorted to, and the mixture of ores was based upon the analysis. The result, after long efforts, has been that the Creuzot Works produce seven distinct types or qualities of iron, denominated by the numbers 1 to 7, which can be relied upon, and which have been well received in commerce. The physical properties of each of these qualities of iron are shown in the succeeding table.

IRON.

*Numerical table of the physical properties of the seven types of iron made at Creusot.**

Pulling-stress.	1.		2.		3.		4.	
Iron in bars. Bars turned to 200^{mm2} of section, and to 100^{mm} long.† / *Sheet-iron.* Specimens cut 1,000^{mm} wide, 2,500^{mm} long, and 10^{mm} to 12^{mm} thick.	Bars.	Sheets.	Bars.	Sheets.	Bars.	Sheets.	Bars.	Sheets.
Permanent elongation at the moment of breaking..	10	......	15	6.5	18	10	21.5	14.6
Charge of breaking per square millimeter of primitive section.	41	......	37.8	33.2	38	33.7	38.5	34.4
Charge of breaking per square millimeter of the section as broken.	51.3	......	55.5	35.6	60.3	37.6	67	40.5
"Striction," (or relation of the primitive section to the broken section.)	0.800	......	0.680	0.940	0.630	0.895	0.575	0.847
Coefficient of quality, hot ‡	40		50		60		70	

	5.		6.		7.	
	Bars.	Sheets.	Bars.	Sheets.	Bars.	Sheets.
Permanent elongation at the moment of breaking..	25	18.2	29	22	34	26.5
Charge of breaking per square millimeter of primitive section.	38.6	34.8	38.75	35.6	39.2	36.7
Charge of breaking per square millimeter of the section as broken.	73.6	43	83.5	48	112	55
"Striction," (or relation of the primitive section to the broken section.)	0.524	0.808	0.462	0.740	0.350	0.665
Coefficient of quality, hot ‡	80		90		100	

* The figures given in this table are the result of numerous trials; nevertheless they are only comparative and approximate.

† The bars used were all carefully and exactly brought to the same dimensions, and were tested in the same apparatus and manner, and by the same persons.

‡ By an empirical process, justified by experience, the comparative value hot is expressed by coefficients of which the maximum, 100, corresponds to the best charcoal-irons.

97. *Commercial steel.*—A similar method of investigation was adopted in respect of the various grades of commercial steel, and resulted in grouping these varieties in three grand divisions, designated respectively by the letters A, B, and C.

The first division, A, includes the great bulk of production of steel; the greater portion of Bessemer and of Martin steel, and some crucible steel made in England, Belgium, and in France. This grade of steel is used generally in rails and other objects of general manufacture.

The third division, C, includes steel of exceptional purity, which, ac-

cording to numerous analyses, is only to be found in the best products of the crucible from charcoal-iron of the best Dannemora brand.

The second division, B, comprehends the steels of intermediate quality between A and C.

The Schneiders have undertaken to realize in their manufacture in the large way each of these three standard types of quality to a degree at least equal or superior to the mean of each, and they have adopted the three marks A, B, and C to designate three grades of steel which they claim to be able to produce with uniformity. They observe, however, that the physical properties of the same metal are so greatly modified by its degree of hardness that it is necessary to take this hardness into consideration.

The elongation of bars of steel under strain varies more with the degrees of hardness than from any small differences of chemical composition. The elongation is an essential quality, which for the same bar varies greatly with the different degrees of hardness. The classification adopted by the Creusot Works is based upon the hardness rather than the composition. Other metallurgists have taken the degree of carburation as the basis of classification.

This basis of elongation being taken for the classification, it became necessary to fix the extremes. For the hardest they have selected a steel which is susceptible of an elongation of 12 to 14 per cent., or an average of 13 per cent., and for the softest, which permits of 34 to 36 per cent., or a mean of 35 per cent., of elongation. They are able to produce at will such steel, and to maintain the production, as regards this quality of hardness and elongation, within the limits of variation of 1 per cent., more or less. They have also been able to subdivide each of these three groups A, B, and C into grades of hardness differing by 2 per cent. of elongation, commencing at 13 per cent. as the basis, only as the extreme limit of elongation recedes, as the purity of the steel increases, they have 9 numbers for quality A, 10 for quality B, and 11 numbers for quality C.

The classification so adopted, with the numbers for each division, and their comparative resistance to pulling-strain, are shown upon the annexed table. The bars used in these experiments were all carefully turned to a diameter giving 200 square millimeters of section, and were 100 millimeters long. They were hardened in oil.

STEEL.

Numerical table of the physical properties of standard steels made at Creuzot, by quality of metal and degree of hardness.

Pulling-strain turned bars, 200mm2 of section and 100mm in length.	Mark of quality.	Degrees of hardness. 1, Not tempered.	1, Tempered.	2, Not tempered.	2, Tempered.	3, Not tempered.	3, Tempered.	4, Not tempered.	4, Tempered.
Permanent elongation at the moment of breaking.	A	13	2	15	4. 8	17	7. 2	19	9. 4
	B	13	3. 8	15	5. 7	17	7. 8	19	10. 2
	C	13	5	15	6. 6	17	8. 6	19	10. 8
Breaking-charge per square millimeter of primitive section.	A	76. 2	117	73. 6	110. 5	70. 3	105. 6	66. 8	96. 8
	B	77. 7	119. 3	74. 9	115	71. 8	108	68. 2	99
	C	79	123	76. 2	118. 3	73. 2	112	69. 8	104. 8
Breaking-charge per square millimeter of the section as broken.	A	95. 2	119	98. 5	120	101	122	103. 2	123. 5
	B	98	125. 2	101	128	104. 2	130. 8	107	133. 5
	C	100. 2	132. 2	104	136. 5	108	141	113	146. 3
"Striction," (or relation of the broken section to the primitive section.)	A	0. 800	0. 980	0. 749	0. 930	0. 697	0. 865	0. 646	0. 790
	B	0. 793	0. 950	0. 740	0. 900	0. 687	0. 827	0. 636	0. 745
	C	0. 788	0. 930	0. 732	0. 867	0. 678	0. 794	0. 617	0. 720
Charge corresponding to the limit of elasticity.	A	39	72	37. 8	68. 3	36. 4	65. 8	34. 9	60. 6
	B	41. 1	78. 5	40	75. 5	38. 8	71	37. 3	65. 4
	C	43. 2	85	42. 2	82	41	78	39. 8	72. 5
Coefficient of quality, hot..	A	120		120		120		120	
	B	125		125		125		125	
	C	130		130		130		130	

	Mark of quality.	Degrees of hardness. 5, Not tempered.	5, Tempered.	6, Not tempered.	6, Tempered.	7, Not tempered.	7, Tempered.	8, Not tempered.	8, Tempered.
Permanent elongation at the moment of breaking.	A	21	11. 1	23	13. 2	25	14. 6	27	18
	B	21	12. 6	23	14. 8	25	17	27	19. 5
	C	21	13. 3	23	16	25	18. 2	27	20. 6
Breaking-charge per square millimeter of primitive section.	A	62. 8	88. 6	58	78. 7	53. 2	68. 6	49. 2	61. 2
	B	64. 4	91	59. 7	82	55	73. 8	50. 5	65. 8
	C	65. 9	99	61. 5	89. 8	56. 8	81. 2	52. 2	72. 6
Breaking-charge per square millimeter of the section as broken.	A	105. 6	125	106. 8	126. 5	108	128. 1	110	129. 7
	B	110. 8	136. 2	113	138. 7	115. 2	142	119	145. 1
	C	115. 5	151. 2	119. 6	156	123. 2	160. 5	127. 5	165. 4
Striction," (or relation of the broken section to the primitive section.)	A	0. 595	0. 710	0. 544	0. 625	0. 493	0. 535	0. 441	0. 473
	B	0. 582	0. 670	0. 529	0. 590	0. 477	0. 520	0. 425	0. 453
	C	0. 570	0. 655	0. 514	0. 575	0. 460	0. 508	0. 409	0. 449
Charge corresponding to the limit of elasticity.	A	33. 2	56. 2	31	50. 3	28. 8	43. 8	26. 6	37. 8
	B	35. 8	62. 1	33. 8	55	31. 8	49. 8	29. 6	44. 7
	C	38. 3	68. 8	36. 5	62. 2	34. 8	56. 9	32. 7	51. 2
Coefficient of quality, hot..	A	120		120		120		115	
	B	125		125		125		120	
	C	130		130		130		125	

Numerical table of the physical properties of standard steels, &c.—Continued.

Pulling-strain turned bars, 200mm² of section and 100mm in length.	Mark of quality.	Degrees of hardness. 9 Not tempered.	9 Tempered.	10 Not tempered.	10 Tempered.	11 Not tempered.	11 Tempered.
Permanent elongation at the moment of breaking.	A	29	21	....	....	....	....
	B	29	22	32	24.2	....	....
	C	29	23.4	32	27.6	35	33
Breaking-charge per square millimeter of primitive section.	A	45	56.2	....	....	....	....
	B	46.7	58.8	41.3	51.2	....	....
	C	48.2	63.8	43.5	53.2	39.3	46
Breaking-charge per square millimeter of the section as broken.	A	114	131.3	....	....	....	....
	B	123	147.5	127	152	....	....
	C	132.6	170	140	175.2	146.6	180.5
"Striction," (or relation of the broken section to the primitive section.)	A	0.395	0.428	....	....	....	....
	B	0.379	0.398	0.325	0.337	....	....
	C	0.363	0.375	0.310	0.305	0.268	0.255
Charge corresponding to the limit of elasticity.	A	22.5	33.6	....	....	....	....
	B	27.5	40	23.6	33	....	....
	C	30.7	45.3	27.8	37.2	24.4	32.8
Coefficient of quality, hot..	A	110		....		....	
	B	115		110		....	
	C	120		115		110	

98. Notwithstanding the great number of the experiments and the care with which they were made, the figures are not given as absolutely and mathematically accurate, but as approximations and comparative. They vary of course somewhat according to the operator, the instruments, the form, and the preparation of the specimen, and, further, according to the intrinsic qualities of the metal. The bars, however, were all formed, as nearly as could be, in the same manner and turned to the same dimensions, and the experiments were confided to the same person, and were all conducted alike.

99. *Resilience.*—The results published by the Creuzot Works at Vienna comprise, it will be noted, only elongation and "striction," (the relation between the area of the fracture and the original section.) Other experiments upon pressure and blows have been made in great numbers; but owing to the extreme difficulty of breaking the bars, especially among the higher numbers, it has not yet been possible to tabulate all these results. The conclusion, however, is that in a general way, for steel of equal quality, the resistance to shocks has a constant relation to the softness of the metal; therefore, for most uses, and particularly for machinery, preference should be given to soft steel.

100. The experiments have not only been laborious but delicate,* and have occupied years of time. The tabular statements represent only the first part of a series which the Schneiders contemplate publishing,

* For ascertaining the charge corresponding to the limit of elasticity, the experimenter used the cathetometer of Froment, with two lenses.

and these were presented in advance simply on account of the exhibition. Chemical investigations of all the steels and the materials used are also in progress.

Each pouring of steel at the works is submitted to physical tests, and these are combined from time to time with chemical analyses, and these investigations are conducted in such a manner that the production of steel is under the closest surveillance and control, and can always be kept within the prescribed limits as to quality.

101. *Deductions.*—The examination of the tabulated results here presented suggests some general conclusions. In regard to the hardness, it is seen that it is less affected by the tempering in proportion to the softness of the metal. At the extreme of the grouping and for the purest metal the hardening does not greatly affect the elongation, but increases the other properties. This metal is a kind of homogeneous iron, or melted iron, the chemical composition of which is the same as that of the best charcoal-irons. We pass by insensible degrees, in a chemical point of view, from the hardest steel to the softest iron, with this great difference always, that the iron is produced by the agglutination of elements more or less thoroughly welded, while steel is the result of fusion, which assures its homogeneity, and gives it special qualities.

102. The second observation is that, under the generic name of *steel*, some thirty different qualities are recognized and differentiated by their physical properties and by their chemical constitution, giving distinct metals, so to speak. There is no resemblance between quality A, No. 1, and quality C, No. 11. The name is the same, but the substances are different. This apparently very simple matter is of great importance in practice. A failure in an application of steel proves nothing against it, but rather against the choice made of the quality, which may not have had any adaptation to the purpose in view.

It is impossible to define "good steel" in an absolute manner. Tool-steel is not adapted to the construction of machines. It is the same with iron. A quality which is excellent for sheets, gives miserable rails, and reciprocally. In the varieties of iron and of steel made at Creuzot, each purpose or application of these substances may find its appropriate quality. The product best adapted to the end in view may be selected with confidence. The tables which are published are intended as a guide to the consumer, who will select the number of iron or steel which has the physical qualities best suited to his purpose. The following general statement is also to be considered:

Rails are always made of quality A, of which the numbers of hardness range from 1 to 5, according to the preferences of railway companies, the conditions of track, climate, traffic, &c. French railways generally use hard rails; American, soft rails; and Russian railways prefer rails of intermediate quality. For tires, parts of machines, axles, sheets, &c., the higher numbers of quality A are most used, but it is

better to use quality B. The quality C is used for special purposes, such as certain plates, axles, ordnance, and other exceptional objects which require the greatest possible strength of metal.

103. For commercial purposes, use is made of the annexed tables of price and of hardness.

Increase of price according to quality, hardness, &c.

Marks.	Increase of cost per 100 kilograms.	
	By quality.	By hardness numbers.
Creuzot A	0 francs	From 1 to 7, inclusive, 0 franc.
Creuzot B	15 francs	From 8 to 11, inclusive, 2 francs.
Creuzot C	30 francs	(Per number.)

COMMERCIAL HARDNESS TABLE, CREUZOT.

Approximate elongation obtained on bars 200 *square millimeters of section and* 100 *millimeters long.*

Marks.	Classification numbers.										
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Quality A	13	15	17	19	21	23	25	27	29	....	....
Quality B	13	15	17	19	21	23	25	27	29	32	....
Quality C	13	15	17	19	21	23	25	27	29	32	35

IRON LINING FOR MINING-SHAFTS.

104. The company *des Hauts-Fourneaux de Marquise* exhibit large cast linings for circular shafts sunk on the Chaudron and Kind systems. They have made these linings of the following diameters:

	Exterior diameter.	Interior diameter.
1868	$2^m.40$	$2^m.16$
1868–1871	3 .45	3 .21
1872–1873	3 .89	3 .65

They have supplied linings to the following localities:

	Height of column.
Escarpelle Company, France	$87^m.00$
Escarpelle Company, France	75 .00
Calcasieu, United States, Louisiana	135 .00
Meuschin, France	75 .00
Douchy	49 .50
De Liévin	70 .50

The maximum thickness of these linings is 45 millimeters. They generally will sustain a pressure of nearly 13 atmospheres; the maximum is 18 atmospheres.

VARIOUS EXHIBITS, FRANCE.

105. The establishment of Revollier Bietrix et Cie., St. Etienne, exhibit cast-steel tires, and a number of other firms of the Loire united in

a collective exhibition of considerable interest. The *Société Anonyme des Acieries et Forges* of Firminy, Loire, under the direction of F. F. Verdie, manufacture railway material, rails, axles, tires, cast steel, &c. They have a capital of 3,000,000 francs, and a production in 1872–'73 valued at 10,000,000 francs. They produce 21,600 tons of pig-iron annually.

The *Société des Acieries à Ermont* exhibit a variety of articles of cast steel in illustration of the Lesset process, (3 Boulevard Hausman, Paris,) consisting of wheels, plowshares, ornaments, cog-wheels, tools, gratings, railway-frogs, axes, &c. Some grape-leaf ornaments are very sharp and delicate, with a fine surface. The samples are malleable, and bear doubling up when heated. The same firm send a large drawing, in colors, of a furnace for heating crucibles by Ponsard's process, illustrated also by folio plates published by the *Société Métallurgique pour l'exploitation du procédés Ponsard.*

106. ALGERIAN ORES.—There are some masses of specular iron-ore from the departments of Oran and of Constantine, also hematites and siderite and peroxide of manganese. These are shown by the mining department of Algeria. The ores of Mokta-el-Hadid appear in the exhibition made by Creuzot and by other establishments. The production of iron-ore in Algeria was nearly 400,000 tons in 1872. Mokta-el-Hadid supplied over 350,000 tons. According to Forbes,* the company owning this mine raised and sold 372,849 tons, and divided 7½ per cent. on the capital stock. The profit for 1872 reached the sum of £119,797.

The number of men employed in the iron-mines of Algeria at the commencement of the year 1874 was 2,655. The exportation of iron-ores during the years 1872 and 1873 was as follows, in metrical tons:†

To—	In 1873.	In 1872.
France	267,331	251,528
Netherlands	64,265	40,960
Belgium	13,670	4,290
Germany	....	1,562
England	62,098	61,157
Spain	25	....
United States	11,504	....
	418,893	359,497

The portion shipped to the Netherlands was for transmission to Germany.

* Report on the Progress of the Iron and Steel Industries in Foreign Countries, 1873.
† From reports of David Forbes, 1875.

CHAPTER IV

BELGIUM.

HOPE FURNACE AND MILLS AT LIÉGE; SCLESSIN COMPANY; ROLLED TIRES, OUGRÉE COMPANY; JOHN COCKERILL COMPANY; DESCRIPTION OF THE COCKERILL WORKS, MINES, COKE-FURNACES, ETC.; THE PRODUCTS OF THE WORKS; MINING-MACHINERY.

107. The exhibitors of iron and steel in Group I, from Belgium, are but few, and there is a notable absence of any printed information concerning the iron and steel industry, or indeed any of the industries classed in the first group, while under agriculture, the second group, the catalogue is enriched with statistical descriptions.

The chief exhibitors are—

Société Anonyme des Charbonnages, Haut-Fourneaux et Laminoirs de l'Espérance, at Liége, and at Seraing, near Liége. This company sends samples of coal and coke, and of pig-iron, at 150 francs the 1,000 kilograms, and sheet-iron from 450 francs.

The quantity and value, estimated, of the production of the Belgian iron-works in the years 1871, 1872, and 1873 is given as follows:*

BELGIAN IRON-WORKS.

	1871.	1872.	1873.
Blast-furnaces:			
Number in activity	48	52	54
Pig-iron in tons	609, 230	655, 565	607, 373
Value	£4, 794, 552	£2, 616, 823	£2, 809, 929
Founderies:			
Number of works	174	168	176
Production in tons	70, 427	79, 863	81, 393
Value	£538, 561	£841, 685	£1, 000, 291
Forges:			
Number of works	58	57	53
Production in tons	467, 216	502, 577	480, 374
Value	£3, 369, 787	£4, 979, 254	£5, 570, 002
Iron-workshops:			
Number of works	62	63	54
Production in tons	33, 145	28, 393	23, 058
Value	£474, 119	£427, 962	£428, 025
Iron-mines:			
Iron-ore extracted, tons	697, 272	749, 781	503, 565
Value	£253, 107	£295, 617	£240, 891
Steel:			
Number of steel-works	2	3	3
Production in tons	8, 900	15, 284	19, 050
Value	£126, 800	£231, 240	£311, 200

* *L'Annuaire statistique de la Belgique*, cited by David Forbes.

The official returns published by the ministry of finance show the following as the importations and exportations of iron-ores and cast and wrought iron of every description:

IRON-ORES.

	Importations, in metrical tons.			Exportations, in metrical tons.		
	1874.	1873.	1872.	1874.	1873.	1872.
Germany	542, 996	487, 468	586, 038	1, 268	35, 299	34, 162
Netherlands	13, 522	9, 467	13, 656	14, 536	56, 555	41, 187
England	4, 744	380	624	3	192	....
France	180, 401	227, 247	180, 360	92, 355	122, 993	103, 647
Spain	19, 763	10, 013	7, 932	....	....	....
Italy	800	191	....	....	....	....
Algeria	2, 549	4, 016	1, 966	....	....	....
Sweden and Norway	1	755	14	....	....	....
Other countries	2	....	....	40	....	....
Total	764, 778	739, 536	790, 590	108, 202	215, 029	178, 996

CAST AND WROUGHT IRON.

	Importations, in metrical tons.			Exportations, in metrical tons.		
	1874.	1873.	1872.	1874.	1873.	1872.
Pig and scrap	161, 485	145, 211	137, 008	11, 137	27, 207	49, 096
Castings	1, 175	1, 265	981	5, 096	5, 265	5, 023
Bar-iron	2, 546	2, 508	3, 090	2, 937	2, 211	2, 611
Rails	14, 431	9, 677	7, 512	92, 226	72, 942	81, 495
Plates and sheets	422	1, 279	562	26, 090	18, 910	24, 282
Other wrought iron	3, 265	4, 710	3, 823	103, 807	87, 597	101, 654
Anchors and chains	94	111	78	5	17	31
Nails	577	477	341	11, 066	9, 765	13, 346
Other manufactured iron	3, 221	3, 588	3, 536	16, 555	12, 802	15, 380
Total	187, 216	168, 826	156, 931	268, 919	236, 716	292, 918

108. BEAMS, GIRDERS, ETC.—*Société Anonyme des Hauts-Fourneaux, Mines et Charbonnages de Sclessin*, near Liége. This company exhibits a variety of beams, girders, round iron and steel, angle-iron and segment-iron for forming hollow posts, and iron and steel rails, for all of which they claim superiority of form and manufacture. Their list of prices (November, 1872) is as follows:

	Francs.
Girders, 300^{mm}, price per % kilograms	46. 00
250, 237, 235	44. 00
135 by 150 and 130 by 150	40. 50
Segmental iron for beams and posts	38. 00
Iron rails	32. 00
Steel rails	46. 00

109. ROLLED TIRES.—The Ougrée Company of Seraing, (*Société de la Fabrique de fer d'Ougrée à Seraing, près Liége,*) of which M. Mockel is

the general director, makes a fine exhibition of rolled weldless tires for railway-carriages, tenders, and locomotives; also car-wheels and axles, all either of fine-grained iron, puddled steel, or Bessemer steel. The tires are beautifully arranged one above another, held together by bands and bolts, so that they form a high pyramid, with the smallest tires at at the top. One of the tires shown is 10 feet or more in diameter. The rings of steel from which the tires are rolled are also shown, together with numerous illustrative sections of axles and tires displaying the quality of the material.

This establishment was founded in 1836. It has participated in most of the great international exhibitions, and has received numerous medals.

JOHN COCKERILL COMPANY, AT SERAING.

The principal establishments of the Cockerill Company are situated at Seraing, Belgium, six miles from the town of Liége, in the valley of the Meuse, upon the carboniferous formation which runs through the territory. They occupy the estate which was used as a summer-residence by the bishop-princes of Liége until the end of the last century.

110. *Société John Cockerill.*—But by far the most important exhibition in this department from Belgium is that made by the celebrated works of John Cockerill, concerning which interesting information was freely supplied, and is as freely used.

The works comprise coal and iron mining, the reduction of the ores, the fabrication of cast and wrought iron and steel, the construction of machines and mechanical and manufacturing engines, boilers, metallic bridges and vessels.

The management is vested in a board composed of five members, assisted by a director-general.

The establishments comprise the offices for the direction, a special engineering service for the studies of construction, a library, and a laboratory for analyzing the raw materials. There are, as respects the working, eleven special divisions, managed by chief engineers.

The foundation of the Seraing establishments is due to John Cockerill, born at Haslington, Lancashire, on August 3, 1790. His father had in 1799 introduced at Liége the construction of machines for wool-spinning, and, after having acquired there a great fortune, left, in 1813, his factories to his two sons, James and John.

Coal and iron mining, the smelting of charcoal pig-iron, and wrought-iron works had been organized in the Liége territory for centuries. Besides husbandry and connected occupations, the working class of the country was mostly composed of coal-miners, smelters, blacksmiths, cutlers, nail-makers, lock and gun smiths. Materials and workmen were not wanting.

In 1817, Cockerill Brothers bought from the Netherlands government the palace of Seraing, with its appendages, and established at first works for the construction of steam-engines and machines for spinning flax, and afterward a flax-spinning mill.

John Cockerill came to reside at Seraing in 1822, and bought the grant of coal-mines upon which the works stand, and took the proper measures to introduce on the continent the smelting of cast iron with coke and the fabrication of iron according to the English process.

The working of the factory was then chiefly supported by orders from the Netherlands government. In 1824, magnificent steam-engines of 300 horse-power were constructed under John Cockerill's supervision for the men-of-war of the country, while the English navy had engines of 150 horse-power only.

In 1826, the first coke blast-furnace, the furnaces, the rollers, the hammers, the blast-engines, and the engines for the iron-factory, were used. The coal-pits were fitted up with powerful exhausting and drawing machines.

The first continental railway was decreed by the Belgian government after the revolution of 1830, and the first locomotive was constructed for that railway in 1834, by the Seraing Works, which, soon after, supplied all the engines for the beginning of the Belgian net-work of railways.

The Seraing establishment continued to increase rapidly until the demise of John Cockerill, which happened in 1840. It comprised, in 1842, at the formation of the joint-stock company—

1st. The grant of coal-mining, with three collieries furnished with all the pumping and lifting engines.

2d. Thirty-seven coke-kilns of large size.

3d. Two blast-furnaces with steam-bellows, and grants of iron-mines.

4th. A vast iron-smeltery and a copper-foundery.

5th. An iron-factory, with 35 reverberatory furnaces, 5 sets of rollers, the hammers, the divers steam-engines, the tools and apparatus to complete the fabrication.

6th. An engine and boiler factory, containing 144 forge-furnaces, 280 lathes and boring-machines, 200 planing, grooving, tapping, and perforating machines, &c.

There were 2,200 employés and workmen.

The moving power was equal to 920 horse-power.

The Seraing establishments were placed, in 1829, by John Cockerill, under the general superintendence of Gustave Pastor, his nephew, and the latter continued his services when the company was formed until 1866, at which time M. Pastor withdrew and was replaced by M. E. Sadoine, chief engineer of the government navy, now the general director.

The gradual improvements of the works, continually enlarged, have brought the productive powers of the various divisions to their present state. They now comprise—

Coal-mines.—Four collieries, with 8 shafts for raising the coal to the top, ventilation, exhaust, letting down and bringing up the workmen by Fahrkunst; 24 engines, together of 900 horse-power; 2,400 workmen Since 1867, women work no longer in the collieries of the company. Annual production of fuel, 350,000,000 kilograms.

Coke-furnaces.—Four groups comprising 143 horizontal kilns, 12 groups comprising 216 Appol kilns, 3 hammers, and 6 washers; 6 steam-engines to pull out the coke, 13 steam-engines of 168 horse-power collectively; 140 workmen. Annual production of coke, 140,000,000 kilograms.

Iron-mines.—Thirty mines in the Belgian provinces of Liége and Namur, in Luxembourg, and in Spain. Seventeen engines, equal to 306 horse-power; 800 workmen. Annual production of the mines, 150,000,000 kilograms.

Blast-furnaces.—Five blast-furnaces, with apparatus for heating the air, and tapping-sheds for ordinary casting, yielding annually 55,000,000 kilograms; 4 blast-furnaces for steel pig now building; 15 engines, collectively of 480 horse-power; 300 workmen.

Founderies.—Two iron founderies and one of copper, 2 workshops for earthen molding, steam-cranes, 1,000,000 kilograms foundery frames; 6 engines, of 90 horse-power collectively; 280 workmen. Annual production, 5,000,000 kilograms.

Iron-works.—Seventy-five reverberatory furnaces, 12 rollers, 7 hammers; 55 engines, of 1,900 horse-power collectively; 1,240 workmen; 40,000,000 kilograms in rails, girders, bar and sheet iron as annual production.

Steel-works.—Ten Bessemer converters from 5 to 7 tons, 6 of which are being mounted; 16 reverberatory furnaces, 7 hammers, 4 rollers; 46 engines, of 3,079 horse-power collectively; 560 workmen; 17,000,000 kilograms steel as annual production, before the use of the unmounted apparatus.

Forges.—Twelve reverberatory furnaces, 7 hammers, 70 forge-furnaces; 5 engines, of 288 horse-power; 200 workmen; 1,500,000 kilograms mechanical pieces as annual production.

Engine-shops.—Three hundred and sixty-eight lathes, mortisers, planers, perforators, tap-borers; 5 machines to forge bolts and screw-nuts; 2 hydraulic presses; moving-cranes, stationary steam-cranes, and others; 20 engines; 1 hammer of 264 horse-power; 1,400 workmen; 7,000,000 kilograms machines and mechanical apparatus as annual production.

Bridge and boiler building.—Fifty-five drilling, arching, cutting, planing, canting, and clinching machines; 3 hammers; 54 forge-furnaces; 11 engines, of 120 horse-power collectively; 510 workmen; 6,000,000 kilograms boilers and bridges of various kinds as annual production.

Antwerp ship-building yard.—Stock of tools appropriate for a ship-builder's yard, covered stocks, rafts and boats, shear, slides and slips for launching sea and river steamers; steam-carpentry and joinery; 2 engines of 15 horse-power; 680 workmen; 2,500,000 kilograms naval constructions as annual production.

Interior conveyances and forwarding.—Fifteen locomotive-engines, from 10 to 15 horse-power, employed on the junctions of the interior railways with the North line; 420 workmen; 60 horses, 15 of which in the collieries.

112. *Miscellaneous statistics.*—The area of the works is 200 acres, intersected with 22 kilometers railways of large section, and 12 kilometers of small; containing, besides, a basin communicating with the Meuse by a canal, and 2 wharves.

In 1872 there were 8,912 people occupied, employés and workmen, for all the works.

There were 254 steam-engines, of 7,834 horse-power in all.

The wages paid annually amount to 8,500,000 francs.

The consumption of fuel amounts to 350,000,000 kilograms.

The production of the divisions is 25,000,000 to 30,000,000 francs.

The establishment owns on the heights of Seraing, in a very healthy situation, a vast infirmary, kept by nuns; it holds eighty-five beds. A special physician is attached to it. An orphan asylum, containing at present forty-one children of both sexes, adjoins it.

The establishment possesses also a dispensary, which delivers medicines gratuitously to the persons attached to its works and their families.

In each division there is a refectory established after the best manner, for the meals of the workmen and the preservation of their food; some kitchens are added to several of these refectories, and some baths are put up at the collieries for the miners.

Lastly, a society for relief and pensions is instituted, without being compulsory, for the people of the works, and the establishment accords besides, out of its own funds, temporary relief and pensions to the workmen and employés not concerned in that society.

The Seraing works have constructed, (January 1, 1873:) 2,100 steam-engines, from 4 to 600 horse-power, for all manufacturing purposes; 900 locomotive-engines; 31,500 sets of mechanical apparatus and various pieces for manufactories, complements for factories, repairs, for mining, the reduction of ores, the fabrication of metals, buildings, sugar-works, plate-glass manufactories, paper-mills, spinning-mills, trellis and suspension bridges, iron-clad turrets, &c.

The ship-yards of Antwerp and St. Petersburg (the latter discontinued) have supplied navigation with 282 sea and river steamers, yachts, mail-steamships, steam-tugs, pilot-boats, light-ships, dredging-machines, transport-ships for travelers and merchandise, transatlantic packets, floating docks for iron-clad frigates of the first class and monitors.

The Cockerill Company has facilities and implements sufficient to supply annually 100 locomotives; 70 steam-engines, from 4 to 1,000 horse-power and above, for maritime navigation; 1,500 sets of mechanical constructions, complete works, special apparatus, repairs, &c.; 6,000 tons various bridges, turn-tables, &c.; sea and river steamers of 5,000 tons burden altogether; besides the surplus not consumed in its works of fuel, ores, cast and wrought iron, rails, and steel above mentioned.

At Liége, by the initiative of Cockerill, senior, the first factory for spinning-machines was established on the continent, and at Seraing, by John Cockerill, the first coke blast-furnace and the first puddling-fur-

nace was put into operation, and afterward the first coke-kilns were erected for the making of iron after the English method.

The first steam-engine, and afterward the first locomotive-engine, on the continent were constructed at Seraing.

From 1824, besides the large steam-engines for maritime navigation, the Cockerill establishment constructed very powerful steam-engines for the drainage of the collieries of the Liége Valley, where they are still working.

The establishment has been constantly improving, and has from its foundation maintained the first rank for its various productions, as shown by its uninterrupted growth, the steady increase of its business, and its success in all the exhibitions in which it has taken part.

It exhibits at present at Vienna the following constructions and products:

113. *Packet-boat engine.*—Marine engine of 220 nominal horse-power for the mail-service of the Belgian government between Ostend and Dover.

The steamers carrying the mail between Belgium and England are remarkable for their great and regular speed, their accommodations, and, above all, they are appreciated for their nautical qualities in stormy weather. Their speed in calm weather reaches 17 knots an hour, and is not exceeded by that of any other Channel steamer. The average passage during six months, between Ostend and Dover, has been 4 hours 4 minutes.

This result is not inferior to that of the steam-packets between Holyhead and Dublin, of 2,000 tons, with engines of 750 horse-power.

This speed is owing to the perfect forms of the ships, to the relative power, to the combination and excellent make of the engines.

The latter have given at the official trials a power stated at nearly 1,600 horses.

The brilliant success obtained by the first of these ships, supplied in 1866 to the Belgian government, the Louise Marie, and the requirements of the mail-service, induced the government to cause seven of these steamers to be built without the least change of model. Six are running regularly. The engine destined for the seventh is at the exhibition.

All the principal forged pieces are Bessemer steel, coming from the steel-works of the Cockerill Company, such as the shafts, the connecting-rods, and the columns.

The ships have been built in the ship-yard of the company at Antwerp; the engines in the works at Seraing. Length at water-line, 200 English feet; breadth, extreme, 20 English feet; depth, 13 feet 3 inches; register, gross, 568 tons; draught with 40 tons of coal, 7 feet; register, net, 505 tons.

The dimensions of the engines are as follows:

Diameter of the cylinders, 58 inches; stroke of pistons, 4 ft. 6 in.; ex treme diameter of the wheels, 21 feet; breadth of the paddles, 7 ft. 10 in.; pressure per square foot of the boilers, 30 pounds.

The magnificent steamer Alexandre II, built by the company for the

Volga, is provided with engines similar to those exhibited. That ship is the first "People's Line" steamer navigating the European rivers.*

114. *Blowing-machines for blast-furnaces.*—The style of vertical blowing-machine used is peculiar to the Cockerill Company, and has received the name of "Seraing system."

The first machine of that system, with high pressure, without expansion or condensing, was built in 1853. It has been working twenty years without requiring any other than ordinary repairs.

Since that epoch this style of engine has constantly been improved. The condensing and expansion in two Woolf-system cylinders has been added. The results obtained have been such that the machine exhibited is the one hundred and third of that style constructed by the Cockerill Company, besides twenty-four more now in construction in the Seraing works.

The number would be much greater had the company been able to fulfill all the orders received.

The advantages of the system come from the direct action between the impelling and resisting power, from the great length of the strokes with moderate swiftness of the pistons, from the strong expansion accomplished in two cylinders, and from the condensation.

The blowing-machines constructed by the Cockerill Company vary much in size. The machine exhibited is of the largest model hitherto built; but there are some still more powerful now in construction.

The wind-cylinder of the machine exhibited is 3 meters in diameter, and the length of the piston-stroke is 2.44.

In usual working, the machine makes 12½ revolutions per minute, and

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*The following report from M. Delcourt, chief engineer of the naval department, gives an idea of the working of these engines:

"ANTWERP, *February* 6, 1875.

"SIR: You request me by your letter of the 4th instant to address you a report on the working of the oscillating engines of 220 horse-power of the mail-boats between Ostend and Dover.

"I am happy in being able to state that those engines, some of which have been working nearly six years, have highly satisfied us, and answer peculiarly well our special service.

"As you are aware, that service requires a perfect regularity and a speed maintained in foul weather. Never having but a limited number of boats, considering the rapid increase of our intercourse with England, we have been particularly favored, insomuch that, except a few contingencies, the keeping in repair and repairing of our engines have never required longer than the time allotted for the usual stoppage of our steamers, which is never considerable. To give you an idea of it, the Leopold steamer has performed no fewer than 896 passages between Ostend and Dover, and *vice versa*, from March 4, 1869, until the 1st of January, 1873, which gives a distance gone over of about 55,000 miles of 1,355 meters.

"In short, the engines of our mail-boats, by their simplicity and their excellent mounting, have required but very few repairs, and have allowed us to perform an excellent uninterrupted service, notwithstanding the very small number of our boats considering the great quantity of passages we had to make.

"I am, sir, your obedient servant,

"G. DELCOUR,

"*Chief Engineer of the Naval Department.*

"To the DIRECTOR-GENERAL."

with an effective pressure to the boilers of 4 atmospheres, it gives, per minute, 250 cubic meters of wind with a pressure of 20 centimeters.

The Cockerill Company builds also powerful vertical blowing-engines for Bessemer-steel-works, compressing the wind at 1½ effective atmospheres.

The productions of the Seraing founderies being altogether remarkable for the beauty of the workmanship and of the molding, and the absence of defects, a rough column of blowing-machine, such as it comes out of the mold, is also exhibited, and is truly a fine piece of casting.

115. *Locomotive-engines for the railway company of Upper Italy.*—Dimensions of the engine: number of wheels, all moving, 6; diameter of wheels, 1.31 meters; space between wheels, 3.37; diameter of cylinders, 0.45 meter; stroke of pistons, 0.65. Furnaces: interior height, 1.60 meters; depth, 1.265; breadth, 1.086. Brass tubes: number, 195; length between plates, 2.25 meters; exterior diameter, 0.05 meter. Interior diameter of the boiler, 1.33 meters; weight of the empty engine, 30,674 kilograms; weight of the loaded engine, 34,376 kilograms. Extreme dimensions: length, 8.542 meters; breadth, 2.900; height, 4.260.

The locomotive-engine is exhibited as a specimen of good construction and of perfection of workmanship.

The company has supplied the railway company of High-Italy with forty-seven engines of this style, and is now constructing twenty-four for the same railways.

Small locomotive-engines for stations and service of the works.—The Cockerill Company has constructed within three years small locomotive-engines with vertical boilers for the interior traffic of its works.

The excellent results obtained, as well for the service as for economy, have been so successful that sixty-three of these engines have been supplied to manufacturers, and a dozen are in construction.

Ten engines of that style, besides more powerful ones previously constructed, are employed for the traffic in the Seraing Works.

The company constructs three types of these engines. The first can draw, horizontally, a load (engine not included) of 60 tons; the second draws, under the same conditions, 90 tons; and the third, 160 tons. The engine exhibited is of type No. II.

The dimensions are as follows: Number of wheels all coupled, 4; diameter of wheels, 0.605 meter; space between the axle-trees, 1.400 meters; diameter of pistons, 0.200; stroke of pistons, 0.250; total fire-surface, 8 square meters; contents of the water-tanks, 0.675 meters; contents of the coal-bunkers, 0.195; rough weight, when used, 7,500 kilograms; length, 2.220 meters; breadth, 2.110 meters; height on rails, 3.150 meters.

116. *Perforators for mining or rock-drills.*—From the beginning of the boring of Mount Cenis, the Cockerill Company participated in that great work.

The first air-compressed engines used at the Coscia, at Genoa, as trial, were constructed at Seraing.

The excellent results obtained, the great productive means of the company, and the active concourse that the illustrious author of the boring of the Alps, Mr. G. Sommeiller, met at Seraing, induced the Italian government to intrust the Cockerill Company with the construction of all the mechanical working-stock, without exception, necessary for the boring of the great tunnel.

The company has supplied for the boring of the Alps more than four million francs' worth in engines of all kinds; wheels, water-wheels, water-column engines, compression-machines, perforators, air and water conveyers, &c.

The construction of air-compressed engines and perforation by machinery has since become a special branch, carried to a high degree of perfection.

Fifty compressing-engines have been constructed in its works, more than five hundred perforators have been sold to manufactories, and numerous machines of that kind are now in construction. Mechanical drilling has greatly increased of late. The Cockerill Company uses it in its collieries, and it has supplied the Belgian and French collieries, &c., with many complete sets, and is continually receiving orders for machines of that kind.

Appreciating the experience acquired by the Cockerill Company, and acknowledging the superiority of the system, the St. Gothard Tunnel Company made an agreement for the supply of a part of the compressing and perforating machines it requires.

Two drilling-machines are exhibited.

The first has a certain historical interest. It is one of the machines employed by Sommeiller at Mount Cenis, where it has been for a long while in use.

The second is a simplification and modification, made from that of Mount Cenis, by MM. Dubois and François, engineers at Seraing. This perforating-machine is constructed by the Cockerill Company for mines, and has been chosen for the boring of the St. Gothard.

117. *Steel and iron forgings.*—The production of large forgings (the crank-axles for locomotives, the crank-shafts for sea and river steamboats, the locomotive and wagon wheels, &c., in short, the mechanical forgings of all sizes and shapes) has always been one of the branches for which the Seraing works have enjoyed merited reputation.

The fabrication of locomotive and wagon-wheels principally, forms a special branch of the large forges of Seraing, by a peculiar process for which the company has patents.

As specimens of its usual manufacture, the Cockerill Company exhibits a moving-wheel of 1.30 meters diameter, weighing 783 kilograms; a wheel of locomotive-engine 2.20 meters diameter at the revolving circle, weighing 731 kilograms; a locomotive-wheel, wrought-iron plate, 1 meer diameter, gross weight 520 kilograms; a box for locomotive-engine, weighing 79 kilograms; a head of locomotive-piston, weighing 75 kilograms; a support for locomotive-slide, weighing 95 kilograms.

118. *Production of the steel-works.*—The Cockerill Company has long had in its establishments of Seraing a considerable steel-work; vast buildings for its enlargement will soon be finished.

That part of the works supplies the other parts of the establishment for the construction of machines and manufactures with special productions of varied forms.

Rails, tires, machinery of every kind and size, gun-barrels, guns, and hoops for large-caliber guns are manufactured there.

As specimens of finished mechanical pieces, the Cockerill Company exhibits the piston-rods, connecting-rods, cranks, crank-shafts, levers, pivots, &c., of the marine engine which it exhibits, and also, as special productions of usual workmanship, rails, tires, springs, straight and crank axles, steel plates; a steel hoop with trunnions for cast-iron gun of large size, (an 80-pounder, diameter, 0.24 meter); a steel hoop without trunnion for the same gun. These hoops are destined for the government of the Netherlands. A field-piece;* an assortment of gun-barrels; a collection of various patterns.

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* *Summing up of the experiments made by the Belgian government with a Bessemer-steel gun of the John Cockerill Company.*—The experiments have been divided into two series; the object of the first series was to ascertain the hardness of the steel, the second series the resistance to the corrosive action of the gases and powder, and the absolute resistance of the steel, (cohesiveness, resistance to bursting.)

The gun was at first bored caliber 4, so as to be able to take off the impressions produced by the first firing.

Ten shots with 1½ kilograms powder, 1 wadding, with box for ball, weighing 3.3 kilograms.

Five shots with the same load and some *débris* of projectiles inclosed in linen bags.

After this firing, the piece was brought back to the royal gun-foundery to be examined and bored caliber 6, (95.5 millimeters.)

No apparent damage could be discovered.

Second series.—Five shots with 1 kilogram powder, 1 wadding, 1 ball; 5 shots with 1½ kilograms powder, 1 wadding, 1 ball; 5 shots with 1½ kilograms powder, 2 waddings, 2 balls; 5 shots with 1½ kilograms powder, 3 waddings, 3 balls; 5 shots with 1½ kilograms powder, 4 waddings, 4 balls; 5 shots with 1½ kilograms powder, 5 waddings, 5 balls; 5 shots with 1½ kilograms powder, 6 waddings, 6 balls; 5 shots with 2 kilograms powder, 6 waddings, 6 balls; 10 shots with 3 kilograms powder, 5 waddings, 5 balls.

The experiments determined by the war-minister being terminated, the gun was brought back to the foundery to be examined.

No apparent injury was ascertained by this examination.

The officers of artillery composing the board asked the war-minister for his consent to continue the experiments. The firing was renewed in the following manner: 5 shots with 3 kilograms powder, 6 waddings, 6 balls; 5 shots with 3.5 kilograms powder, 6 waddings, 6 balls; 5 shots with 3.5 kilograms powder, 7 waddings, 7 balls; 5 shots with 4 kilograms powder, 7 waddings, 7 balls; 10 shots with 4 kilograms powder, 8 waddings, 8 balls.

With the load of 4 kilograms, 8 waddings, and 8 balls, the gun was filled to the muzzle.

The gun was again brought back to the foundery and examined. It was ascertained that the bore was very nearly intact.

The board, struck by the extraordinary resistance of that gun, declared that Bessemer steel was every way proper for the fabrication of field-pieces.

119. *Models of boats and floating lock-gate.*—The works have from their beginning been engaged in constructions for river and maritime navigation.

The ship-yards of Antwerp and St. Petersburg (the latter discontinued) have supplied navigation, as previously stated, with 282 sea and river steamers, which have generally fulfilled, as to solidity, elegance of form, complete internal arrangements, means of propulsion and accommodations, all the conditions stipulated in the agreements. The two iron-clad monitors with turrets, propellers, and machine for turrets, air-exhausters, gun-carriages, centrifugal pumps and accessories supplied to Russia in 1864, had been ordered on the 18th of June, 1863. They were forwarded to be mounted to St. Petersburg at the end of October, 1863, and were delivered to the imperial Russian government completely remounted and armed, after trial, on June 13, 1864, (in less than one year.)

The company can build annually fourteen sea and river steamers of any burden.

The models exhibited belong to some of its most remarkable constructions.

The company exhibits a floating lock-gate and some models of steamers.

The floating lock-gate is intended for the canal of the Danube at Vienna. It is to prevent the pieces of ice coming from the breaking up of the main river entering the arm called the "canal," from collecting there, and thus causing the low parts of the town to be overflowed.

The lock-gate is 153½ Vienna feet in length, 30 in breadth, and 18 feet in height. The iron used for its construction weighs 300 tons of 1,000 kilograms. It has been constructed from the draughts of G. de Engerth, C. E., an aulic councilor and member of the board for the improvement of the Danube.

The statement which this board makes of its labors gives all the details concerning it.

What principally characterizes the specialty of the works, workshops, and ship-building yards of the Cockerill Company is the supply of all the working-stock necessary to railways; of all the implements for metallurgical works, such as blast-furnaces, iron and steel factories, or for mechanical works, steam-engines, stocks of tools, in short, of all steamers, dredging-machines, lighters, machines necessary for the execution of a work such as that of the Suez Canal, or of engines of any kind, with or without steam, propellers, machines and working-stock for the boring of Mount Cenis tunnel. The company also send for such undertakings persons peculiarly suited for mounting, putting in working-order, or the supervision of the various machines which they supply.

CHAPTER V.

THE IRON AND STEEL INDUSTRY OF SWEDEN.

THE COMPLETENESS AND EXTENT OF THE DISPLAY; GENERAL VIEW OF THE PRODUCTION; THE FAGERSTA STEEL-WORKS; LIST OF OBJECTS SHOWN; ANALYSES OF THE ORES USED; COMPOSITION OF THE STEEL OF VARIOUS GRADES; FAGERSTA STEEL GUN-BARRELS; NOTICE OF KIRKALDY'S EXPERIMENTS AND MEMOIR; EXAMPLES OF PULLING-STRESS UPON PLATES ANNEALED AND UNANNEALED; BULGED PLATES; WIKMANSHYTTA STEEL; CONDITION OF THE IRON-MANUFACTURE IN SWEDEN; PROFESSOR ÅCKERMAN'S MEMOIR; THE DISTRIBUTION OF IRON-ORE; SOURCES OF FUEL; TRANSPORTATION; ENGLISH COKE; WATER-POWER; GEOLOGICAL ASSOCIATION OF THE ORES; PRODUCTION OF IRON-ORES AND LOCALITIES; METHODS AND COSTS OF MINING; BOG-ORE AND LIMONITE; PIG-IRON; TRANSPORTATION; BAR IRON AND STEEL; BESSEMER STEEL; MARTIN'S STEEL, CEMENT STEEL, ETC.; ROLLING-MILLS; STATISTICS OF PRODUCTION; CHEMICAL COMPOSITION OF SWEDISH ORES.

120. THE SWEDISH IRON INDUSTRY.—The Swedish contribution is characterized by the number and excellence of the specimens of ores, in large square blocks, which form a very appropriate foundation for tastefully-arranged pyramids of bar iron and steel. It is the best collection of magnetic and specular ores in the exhibition, and was made, at the cost of the Swedish Iron Association, by Professor Åckerman, author of an interesting brochure upon the production of iron in that country. Bessemer steel and Martin's steel, in ingots and bars, are also prominent objects in the collection. Here, too, is found a very complete series of samples of the celebrated Dannemora steel, and specimens illustrating each stage in the manufacture of steel from granulated pig-iron, powdered ore, and powdered coal. There is an extensive display also of spiegel iron from Schisshyttan, containing from 16 to 20 per cent. of manganese. The production of iron-ores in Sweden in the year 1871 reached 662,888 tons; of bar-iron, 187,000 tons; of Bessemer steel, 8,000 tons. The production has been steadily increasing, and will be much greater for the year 1873.

121. FAGERSTA STEEL-WORKS.—This well-known establishment was well represented by the materials used and the products, as will be seen by the following list, which includes the remarkable series of test-specimens shown from the testing-works of Mr. David Kirkaldy:

Bessemer steel from the Fagersta Steel-Works, manufactured without alloy of "Spiegeleisen," or of other cast iron.—(1.) Iron-ores, not roasted; iron-

ores, roasted; lime; pig-iron, with the blast-furnace slag appertaining thereto.*

(2.) Steel ingot, 18 "tum" (21 inches) square, planed; series of 8 "tum' ($9\frac{1}{3}$ inch) ingots, fractured, of various degrees of hardness, with the steel slag appertaining thereto;* series of forged blooms, fractured; plate blooms, fractured.

(3.) Pyramid: Side A, saw-blades; side B, steel for machinery, square and round, from $\frac{1}{2}$ to 5 "tum" ($\frac{7}{12}$ to $5\frac{5}{6}$ inches) in diameter; side C, rails for tramways and angle-irons; side D, steel for springs, from $1\frac{1}{2}$ to 5 "tum" ($1\frac{3}{4}$ to $5\frac{5}{6}$ inches) in breadth.

(4.) For mechanical and engineering works, heavy axles, crank-shafts, other forgings for machinery.

(5.) Railway material: Axles, springs, buffers, (American patent.)

(6.) *a.* Steel for tools and implements; *b.* Mining implements, (bores and sledges;) *c.* Gun-barrels; *d.* Five gun-barrels, subjected to severe testing experiments at Carl Gustaf's Stad Gun-Manufactory, as described in the annexed statement; *e.* Gun-barrel, proved at the Husqvarna Gun-Manufactory, as described in the annexed statement; *f.* A series showing the different stages in the process of manufacturing gun-barrels; *g.* A series of fractures made on steel bars of 1 "tum"($1\frac{1}{6}$ inches) square, of various degrees of hardness; *h.* A series of Bessemer products, taken at different periods during the blow; *i.* Plates for heliography: (a.) Polished plates; (b.) Samples of heliographed plates, together with impressions.

(7.) Steel of different forms, and of various degrees of hardness, proved, as regards its strength, at Mr. D. Kirkaldy's testing establishment, London, by experiments in tension, bending, compression, torsion, &c. A statement of the results is contained in special tables, which are distributed on application to the secretary of the Swedish exhibition.

122. *The iron-ores and limestone* employed at the charcoal-blast furnaces at Westanfors and Fagersta consist of the following component parts:

	Iron-ore from the mines of—			Limestone from Hedkärra.
	Östra Stortägten.	Granrot.	Gröndal.	
Silica	27.49	3.10	6.35	10.82
Alumina	1.30	2.05	1.15	7.15
Lime	2.16	1.20	2.65	36.61
Magnesia	1.76	1.05	3.85	6.86
Protoxide of manganese	0.81	10.40	5.50	1.25
Protoxide of iron	20.74	23.56	22.82	....
Sesquioxide of iron	46.14	52.44	50.78	....
Carbonic acid	....	6.10	5.95	37.18
Phosphoric acid	0.016	0.009	0.014	0.007
	100.416	99.909	99.064	99.877

* For analysis, see Annex No. 1.

The average chemical composition formed by the mixture of these iron-ores with the limestone, employed as flux, is as follows:

	Per cent.	Oxygen.	Oxygen.	
Silica	11.93	6.37		
Alumina	2.50	1.16		
Lime	7.51	7.53	2.14	
Magnesia	2.76		1.10	$\frac{7.53}{4.51}=1.66$
Protoxide of manganese	5.63		1.27	
Protoxide of iron	19.76		4.51	
Sesquioxide of iron	43.89			
Carbonic acid	6.02			
Phosphoric acid	0.013			

Such a charge yields, upon smelting, from 48 to 50 per cent. of pig-iron, which is tapped direct from the blast-furnace into the Bessemer converters, and consists on the average of the following component parts:

	Per cent.
Carbon, combined	3.460
Carbon, graphitic	1.289
Silicon	0.771
Manganese	4.491
Phosphorus	0.027
Sulphur	trace.

The blast-furnace slag contains:

		Oxygen.	Oxygen.	
Silica	41.96	22.83		
Alumina	7.02	3.27		
Lime	25.04	25.65	7.16	
Magnesia	17.75		7.09	$\frac{25.65}{15.78}=1.62$
Protoxide of manganese	6.57		1.48	
Protoxide of iron	0.23		0.05	
Alkalies	not determined.		15.78	
	98.57			

As no alloy of specular iron (*Spiegeleisen*) or of ordinary cast iron is employed, the "blow" must be stopped when the proportion of carbon in the steel is reduced to the proper degree. Notwithstanding this, the steel is entirely free from red-shortness.

The following analyses show the chemical compositions of the various classes of steel employed for the purposes specified:

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
	Per cent	Per cent	Per cent	Per cent	
(*a*) Steel for soft plates, railway-axles, &c	0.085	0.008	Trace.	0.025	Trace.
(*b*) Steel for gun-barrels, shafts, &c	0.25	0.036	0.234	0.022	Trace.
(*c*) Soft steel for tools—saws, &c	0.70	0.032	0.256	0.023	Trace.
(*d*) Hard steel for tools—chisels, turning-tools, &c	1.05	0.067	0.355	0.028	Trace.

An analysis of the slag from the converter, taken at the close of the process, shows its composition to be as follows:

Silica	46.70
Alumina	4.24
Lime	0.48
Magnesia	0.17
Protoxide of manganese	32.37
Protoxide of iron	15.63
	99.59

"I, the undersigned, hereby certify, on requisition to that effect, that barrels manufactured at the Fagersta Steel-Works have, for about the last three years, been exclusively employed for the small fire-arms constructed at the Swedish Government Gun Manufactory for the supply of the army, and that such barrels are still employed for the fire-arms now in course of construction at the said manufactory.

"Stockholm, the tenth day of April, 1873.

"C. G. BREITHOLTZ,

"*Master of the Ordnance*, ("*Fälttygmästare.*")

"Since the commencement of the year 1871, the Husqvarna Arms Manufactory has taken its requisite supply of gun-barrels from the Fagersta Steel-Works, and found the said barrels, both as regards material and make, to be of excellent quality.

"On behalf of the Husqvarna Arms Manufactory Company, (Limited,)

"VICTOR ANKARCRONA, *Managing Director.*"

123. FAGERSTA STEEL GUN-BARRELS.—The following is the report of the proving-experiments upon barrels manufactured at the Fagersta Steel-Works, made at the Carl Gustaf's Stad's Gun Manufactory, in the month of May, 1872:

"The barrels were proved in the proving-house of the manufactory with gunpowder from the Åker's Gunpowder-Mills, of the make of 1865. The testing-balls employed weighed 6 'ort,' (7 drams 11 grains avoirdupois,) and were 0.42 'decimal tum' ($\frac{5}{12}$ inch) in diameter.

"First, three barrels, Nos. 1, 2, and 3, turned and bored as delivered from the steel-works to the gun-manufactory, were loaded and discharged.

"In previous experiments with barrels from the Fagersta Steel-Works, it had been found that no remarkable effect was produced until 1 ball and a charge of 9 'ort' (1 ounce 2 drams 2 scruples 7 grains) were employed. The experiments, therefore, commenced—after the ordinary proof, a testing-ball and a charge of 4.5 'ort,' (5 drams 1 scruple 3 grains)—with the above-mentioned ball and a charge of 9 'ort,' (1 ounce 2 drams 2 scruples 7 grains;) after which the number of balls was increased to 9, with the same charge. The result was, that in two of the barrels the power-gas did not force out the balls, but escaped

through the touch-hole. These barrels were reloaded and discharged with the same result.

"After the lead had been melted away from the inside of these barrels, the experiments were continued with all three; the balls, however, being placed at the muzzles. This proof commenced with 1 ball and a charge of 0.5 'ort,' (1 scruple 16 grains,) and ceased when the charge had been increased to 6 'ort' (7 drams 11 grains) and the number of balls to 5.

"In the following minutes the results of the experiments are more fully stated.

"Subsequently, 3 finished barrels, Nos. 1808, 2511, and 2635, were loaded and discharged.

"Barrel No. 1808, after having been subjected to the ordinary proof, was discharged with the usual sharp cartridge, and a testing-ball, placed 27 'tum' (31½ inches) from the chamber-end of the barrel. The only result was, that a considerable protuberance was produced at the seat of the ball.

"Barrel No. 2511 (rejected on account of defective make) was subjected to a similar proof, with the same result.

"Barrel No. 2635 burst in the proof. In this experiment a testing-ball was employed, and the charge was increased from 1 'ort' (1 dram 12 grains) to 16 'ort,' (2 ounces 3 drams 10 grains,) when the barrel burst, after having borne fourteen times the charge for which it was constructed.

"Carl Gustaf's Stad, the 25th day of May, 1872.

"F. G. TREFFENBERG,

"*Lieutenant in the Royal Göta Artillery,*

"*Working-Officer at the Carl Gustaf's Stád Gun-Manufactory.*"

Minutes taken, May, 1872, at the proving of gun-barrels (Nos. 1, 2, and 3) manufactured at the Fagersta Steel-Works.

Number of discharges.	Weight of the charge in Swedish "ort," (1 ort=1 dram 12 grains, avoirdupois.)	Number of balls.	Observations.
1	4.5	1	Barrels unaffected.
2	9	1	A slight enlargement was produced in all the barrals, at the seat of the ball.
3	9	2	The above-named enlargement was increased, and the caliber on each side of the seat of the ball was also somewhat increased; in addition to which, at the fourth discharge of barrel No. 3, a protuberance was produced before the seat of the ball.
4	9	3	
5	9	4	
6	9	5	
7	9	6	
8	9	7	
9	9	8	
10	9	9	The powder-gas escaped through the touch-holes of barrels Nos. 1 and 2, without the balls being removed from their seats; while in barrel No. 3 the balls were discharged.
11	9	9	Only barrels Nos. 1 and 2 were loaded and discharged, with the same results as in the preceding proof.
			With the balls at the muzzles of the barrels.
1	0.5	1	The powder-gas escaped through the touch-hole.
2	1	1	The balls were discharged; the barrels unaffected.
3	1	2	Do.
4	1	3	An enlargement was produced in the barrels at the seats of the balls.
5	1	4	The powder-gas escaped from the touch-hole of barrel No. 2.
6	2	4	The balls were discharged from barrel No. 2.
7	2	5	The powder-gas escaped from the touch-hole of barrel No. 2.
8	3	5	The powder-gas escaped from the touch-hole of barrel No. 1.
9	4	5	A protuberance was produced in barrel No. 3 at the seat of the ball.
10	5	5	A protuberance was produced in barrel No. 1 at the seat of the ball.
11	6	5	A protuberance was produced in barrel No. 2 at the seat of the ball.

Carl Gustaf's Stad, 25th May, 1872.

F. G. TREFFENBERG,
Lieutenant in the Royal Göta Artillery,
Working Officer at the Carl Gustaf's Stad's Gun-Manufactory.

"On the 27th of March, 1869, a steel gun-barrel manufactured at the Fagersta Steel-Works was subjected to testing-experiments at the Husqvana Gun-Manufactory, in the presence of the undersigned, and during the progress of the experiments the following observations were noted:

"1st proof: A charge of gunpower 1½ 'lod,' (5 drams 1 scruple 16 grains avoirdupois,) 1 testing-ball.

"2d proof: A charge of gunpowder 3 'lod,' (1 ounce 3 drams 12 grains,) 2 testing-balls.

"3d proof: A charge of gunpowder 3 'lod,' (1 ounce 3 drams 12 grains,) 3 testing-balls.

"The above three proofs were discharged without any remarkable result.

"4th proof: 3 'lod' (1 ounce 3 drams 12 grains) of gunpowder, 4 testing-balls. Result: The powder-gas escaped through the touch-hole, the balls remained in the barrel, and had to be removed by melting.

"5th proof: 4½ 'lod,' (2 ounces 2 scruples 8 grains) 4 testing-balls. No effect on the barrel.

"6th proof: 1½ 'lod' (5 drams 1 scruple 16 grains) of gunpowder.

One ball was forced into a position of $7\frac{1}{2}$ 'verktum' ($7\frac{1}{3}$ inches) from the muzzle. Result: A protuberance in the form of an egg was produced in the barrel, at the seat of the ball.

"7th proof: 3 'lod' (1 ounce 3 drams 12 grains) of gunpowder. A ball was driven into a position of 1 'verktum' (1 inch) from the muzzle. Result: The same as in the previous proof, viz, the barrel was enlarged at the seat of the ball.

"8th proof: 3 'lod' (1 ounce 3 drams 12 grains) of gunpowder. The ball at the muzzle. Result: The enlargement above described, produced by the seventh proof, was extended by the eighth proof almost to the muzzle.

"Notwithstanding the barrel, after the discharge of each of the above proofs, was carefully examined, no other results could be discovered than those above described.

"Lastly, it should be observed that the balls employed weighed originally 6.65 'ort,' (7 drams 2 scruples 18 grains,) but after they had been forced into their positions, and, consequently, part of their substance had fallen off, they only weighed 5.50 'ort,' (6 drams 1 scruple 15 grains.)

"Husqvarna, dated as above, and signed by B. Munck, colonel, retired; Emil Ankarcrona, managing director of the Husqvarna Gun-Manufactory; C. E. Norström, lieutenant-colonel; A. J. Gustafsson, inspecting armorer; J. Holmberg, gunsmith; Anders Herrlin, inspecting officer."

124. KIRKALDY'S EXPERIMENTS UPON FAGERSTA STEEL.—Four large glass cases in the rotunda are filled with the specimens of Fagersta steel in different forms, just as they came from the testing-machines of Mr. David Kirkaldy in London. They exhibit the effects of pulling, shearing, and twisting stress, and are described and illustrated in an elaborate memoir by Mr. Kirkaldy, entitled "Results of an experimental inquiry into the mechanical properties of steel of different degrees of hardness and under various conditions; manufactured by Christian Aspelin, Esq., Westanfors and Fagersta Works, Sweden."*

This memoir is elegantly printed and illustrated, and is not only important to engineers and those using steel in construction, but is extremely interesting to the physicist. As an example of the nature of the investigation and of the results obtained, diagrams (Figs. 59 and 60) of two of the steel plates are here given.

These plates, before being subjected to strain, were 10 inches wide at the reduced part, and both edges were accurately parallel for 10 inches of length, and accordingly equal to the breadth or width at the reduced part. The seven holes at each end for connecting the plate to

* By David Kirkaldy. Illustrated by plates and wood-cuts. London, Testing and Experimental Works, Southwark street, S. E. 1873. 4°. Pp. 29, with tables and illustrations.

the massive steel links of the testing-machine were carefully and accurately made in line, and to fit the steel pins exactly. In order to develop or make manifest the change of form of the plates when under stress, some of the plates had circles and others diagonal lines drawn on the surface. The distortion of these lines shows the extent of the yielding of the plate in its different parts.

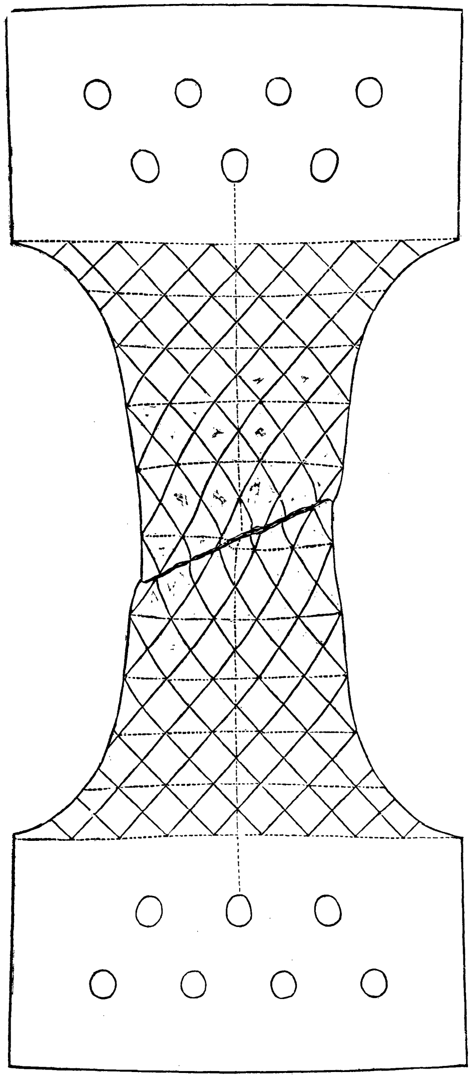


FIG. 59.—H. 1927.—Diagrams of steel plates broken by pulling stress.

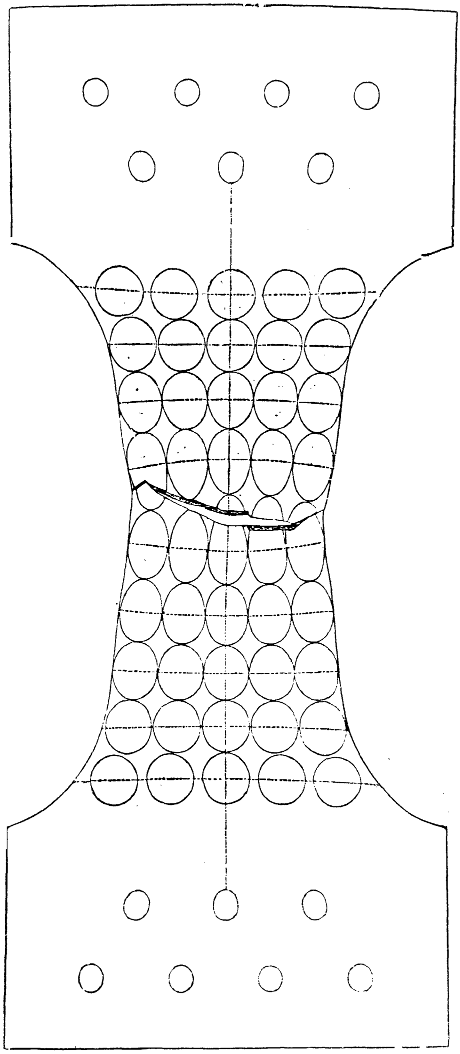


FIG. 60.—H. 1924.

Fig. 59, with the diagonal lining, represents the annealed plate, (H 1927 of the series,) and the plate (Fig. 60) upon which the circles were drawn (H. 1924) was not annealed. Both plates were half an inch thick. The results are tabulated with others in the annexed table.

125. *Deportment of rolled Fagersta steel plates under pulling-stress.*

LARGE SPECIMENS—TEN INCHES WIDE. LENGTH=BREADTH.

Description.	Marked.	Test-number.	Original size.	Original area.	Elastic stress per square inch.	Ultimate stress per square inch.	Ratio of elastic to ultimate.	Contraction of area at fracture.	Extensions, sets at— 40,000 pounds per square inch.	Extensions, sets at— Ultimate.	Appearance of fracture.
	No. in.	*H.*	*Inches.*	*Sq. in.*	*Lbs.*	*Lbs.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	
Unannealed	1. $\frac{1}{8}$	1906	9.95 × .129	1.283	53,300	74,915	71.1	43.1	0.00	10.8	100 per cent. silky.
	1. $\frac{1}{4}$	1912	9.95 × .250	2.487	37,900	60,480	62.7	48.5	0.22	28.2	Do.
	1. $\frac{3}{8}$	1918	9.95 × .380	3.781	29,500	51,456	57.3	59.3	7.33	36.1	Do.
	1. $\frac{1}{2}$	1924	9.95 × .495	4.925	31,100	55,803	55.7	50.0	5.82	36.4	Do.
	1. $\frac{5}{8}$	1930	9.95 × .625	6.218	28,000	52,924	52.9	55.1	6.66	37.2	Do.
Annealed..	2. $\frac{1}{8}$	1909	9.95 × .124	1.233	35,500	57,485	61.8	57.1	1.11	22.9	Do.
	2. $\frac{1}{4}$	1915	9.95 × .255	2.537	33,800	54,543	62.0	60.9	3.90	33.8	Do.
	2. $\frac{3}{8}$	1921	9.95 × .380	3.781	28,900	51,076	56.6	63.4	7.39	35.8	Do.
	2. $\frac{1}{2}$	1927	9.95 × .490	4.875	27,800	51,338	54.2	61.0	8.70	38.5	Do.
	2. $\frac{5}{8}$	1933	9.95 × .628	6.248	25,500	50,432	50.6	62.0	9.98	34.4	Do.

There were several very interesting examples of the effects upon steel plates by pushing them through apertures of less than their own diameter, giving cup or bell shaped objects, highly sonorous, and suitable for gong-bells. This lot of specimens formed Series G of Kirkaldy's memoir, and he describes them as follows:

"*On the effect of bulging-stress on rolled steel plates of various thicknesses.*—The specimens for the above test were disks, twelve inches diameter, cut out in a lathe, and pressed through an aperture ten inches diameter in my testing-machine, the end of bulger being turned to a radius of five inches. The two wood-cuts which accompany the tabulated report of the results Series G, show the form of the specimen previous to and after experiment. Ten pieces were tested as rolled unannealed, and ten after being heated and annealed.

"The following table exhibits the stress required to force the specimens of the various thicknesses through the aperture:

Thickness.	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
Unannealed .... pounds..	215,685	162,735	104,845	71,800	35,397
Annealed .... do....	198,005	154,230	95,605	59,425	25,435

"All the specimens stood the ordeal without the slightest sign of any crack or defect in the manufacture. The clear tone given out, on being struck, by all the specimens after being bulged, excepting those that buckled owing to their thinness, proves the soundness of the material, and consequently its special suitability for some engineering purposes, as well as for bells and gongs. It is only superior ductile materials that will stand this test without cracking or showing signs of laminations or blisters. Circles were drawn on one of the flat disks, H. 1904, and it is curious to observe the change in their form according to their position,

some parts being distended, while the portion toward the circumference is compressed; the original circumference of the specimen being 37.68 inches, and that of the aperture 31.40; difference, 6.28 inches, or 16.6 per cent., which is the amount of compression at the oute edge of the bowl. The material at the inner edge is still more compressed, the amount varying with the thickness. Thus we find in the five-eighth-inch plate the inner diameter is 8.9 inches; circumference, 27.94; difference, 9.74 inches, or 25.8 per cent.; and the depth 3.44 inches at the center of the bowl."

126. WIKMANSHYTTA STEEL.—The Wikmanshytta cast steel is claimed to be especially valuable for mint-dies and for tools, as attested by several certificates, two of which, from Joach. Ackerman, the chief director of the royal mint, containing interesting details regarding the tempering and wear of dies, are translated:

"Upon application made to me to that effect, I do hereby certify that cast steel, made at the iron-work Wikmanshytta, has been almost exclusively employed for coin-stamps in the royal mint of this place for upward of two years, and was found quite as proper to that purpose as the several kinds of foreign cast steel, both English and German, which, during the ten preceding years, have been imported for the use of the mint, as being the then best known steel for the same purpose. In the last five months of the year 1864, when copper coin only, of three different sizes, was manufactured, the stamps or dies of Wikmanshytta cast steel sustained upon an average 30,048 strokes each, and it should here be observed that such copper coin is somewhat harder than the Swedish silver coin of six ounces. As something extraordinary, I beg to state that one pair of stamps—for pieces of 4 riksdaler—have respectively sustained the following number of strokes by the mint-press, viz, that for the reverse side of the coin 90,000, and that for the obverse side more than 130,000 strokes, without either showing the slightest sinking or crack; and both of them were at last rejected owing merely to the fact of the flatter places in the engraving having become worn and indistinct by being repeatedly polished. Of the eight different degrees of hardness, wherein the Wikmanshytta cast steel is assorted, that marked with No. 1 has been found to be the most proper for coiners' stamps.

"Stockholm the 18th of March, 1865."

"I, the undersigned, do hereby certify that during the last five years no other cast steel than that of Wikmanshytta, marked C. R. U. I., has been employed for coin-stamps in the royal Swedish mint at this place, and that the said cast steel, as to strength and durability of the stamps, is found to be superior to the English cast steel of the best known kinds and marks, which were previously employed at the mint for the same purpose; and that it is quite as good as the famous Krupp's cast steel, which, especially manufactured for coin-stamps, was employed for more than one year, whereupon it was again given up on account of its high price. In the course of a coining, commenced some days ago, of

brass pieces of 5 öre, with the same alloyage as that of the imperia French brass coin, a pair of stamps have already sustained 75,000 strokes without showing the slightest defect. Many years ago some large, hardened pieces, belonging to our coining-presses, were made of the same kind of cast steel from Wikmanshytta, and were fitted into the presses, instead of like pieces of other steel which were worn out or split, and the same have proved to be durable and are still perfectly faultless. The individual actually intrusted with the process of tempering the coin-stamps, and who is a clever and intelligent smith, operates as follows: The stamps (one or two to three stamps together) are packed up into a hardening-box of iron plate, in a fine charcoal powder, and are surrounded with clay uppermost at the mouth of the box, still so that their bottoms or lower surfaces, which are turned up, rest free and uncovered. They are then heated by a coal-fire in a small draught-furnace, and when they have the proper temperature, which is ascertained by their color, they are taken up and are refrigerated with pure water in a hardening-tub, from the bottom whereof a feeble dash of water rises against the piece to be hardened through the water standing in the tub, to the height of about 0.75 foot. The stamp is plunged into the water only little by little, in the first place almost nothing but the neck, and then the other part gradually, but the bottom itself is cooled more slowly, without being plunged down into the water. After being fully refrigerated, the stamp is annealed in the following way; that is to say, a suitable thick iron ring, heated to a slight degree of redness, is slowly drawn over the stamp and is kept there until the engraved surface has assumed a yellow straw-color, whereupon the ring is taken off, the tempering having then been finished.

"Stockholm, the 19th November, 1867."

This cast steel is produced by the Uchatius method. Granulated pig-iron is mixed with charcoal and powdered iron-ore of great purity and richness. It is melted in graphite crucibles.

CONDITION OF THE IRON-MANUFACTURE IN SWEDEN.

127. The condition of the iron-manufacture in Sweden at the beginning of the year 1873 is the subject of an important memoir by Prof. Richard Ackerman, assistant in the Mining Academy at Stockholm, prepared to accompany and elucidate the exhibition of Swedish ores, iron, and steel. The memoir may, therefore, be considered as a part of the exhibition, and this, together with its general value to the industry of iron, justifies the presentation of a translation in this place.

128. ACKERMAN'S MEMOIR—TRANSLATION.—Although the Swedish iron-manufacture has been developing steadily, both as to the quality and as to the quantity of the iron produced, still, it cannot be denied that at present Sweden no longer holds the prominent place among iron-producing countries as formerly. This, as will be shown, has been brought about chiefly by natural conditions, which have hindered the

iron-industry; still, Sweden keeps pace with many other countries more densely populated and richer in coal. Sweden, however, is just now in a state of transition to a new period of development, during which, it is reasonable to hope, the iron-manufacture will be brought to as high a degree as is possible in a country which has no mineral fuel in the neighborhood of its deposits of ore.

Far from the quality of the Swedish iron having deteriorated, it has become, in consequence of improved methods of production, not only purer and more uniform and dense, but also has been produced in greater quantity than formerly; for example, the production in 1870 was more than one and one-half times greater than in 1860. In comparison with many other countries it is still very small, in addition to which is the fact that, with a few exceptions, the iron destined for exportation has hitherto been produced only in the form of pig, bloom, bar, or refined iron. The Swedish iron is therefore only occasionally brought to market in manufactured forms, and the manufacture of iron-ware, with the exception of nails, has never been great enough to supply the necessities of the country itself.

129. *Distribution of iron-ores in Sweden.*—The cause of Sweden's producing so little iron does not lie in the lack of ores, for the country, on the contrary, is rich in iron-ore, although its profitable occurrence is limited to certain districts.

The greatest and most extensive deposit of ore is found in a belt running from northeast to southwest, which comprises the southern part of the provinces of Gefleborg and Kopparberg, the northwestern part of Westmanland, the northern part of the province of Örebro, and the eastern of Wermland. Including in this belt Winkärn, in the province of Kopparberg, no other deposit of importance is met with to the north, till as far as Norrbotten, where, indeed, at Gelliwara, and in other places, a great abundance of ore is found. In consequence, however, of injurious compounds, and the scanty population of these regions, up to this time the mines have been worked to only a very slight extent. South of this belt there are very important mines, as Dannemora, in the province of Upsala, and several others in the provinces of Stockholm, Södermanland, and Östergötland. Further still, near the southern end of the Wetter-see, in the province of Jönköping, occurs a great deposit, that of the Taberg. This province borders on that of Kronoberg, rich in bog-iron ores, which are also met with in several other provinces, though in smaller quantity.

Although the richness in ore is thus very considerable, most of the mines at present are not in a condition to yield greater quantities of ore annually, this condition being in turn dependent upon the fact that the demand for ore has been hitherto so limited that the necessary quantity could easily be furnished with the old apparatus. These relations are about to undergo an essential alteration, and the continually increasing consumption of ore will surely demonstrate soon the necessity for a more rational mining-system.

The first condition of sensible mining is that each mine shall belong to not more than one company, while it now happens that one mine is often divided into several parcels, each one of which is worked rather independently, and without proper connection with the other parts, by the different proprietors. Indeed, within the last few years many such pits opened on one mine have come into the possession of one company; but there is much to be done in this direction before the mining-system can reach such a point as to guarantee for the future a sure production of ore, both extensive and cheap.

130. *The sources of fuel.*—In order to bring about a greater production of iron, it is not enough to possess rich sources of ore; the amount of fuel necessary for the smelting and further working of the iron must also be present. It is precisely the small supply of this important element in iron-making which limits the iron-production of Sweden, for mineral coal occurs only in the most southerly part of the country, at Schonen, and possibly also in Southern Halland. The deposits of coal occurring there belong, apparently, to the Liassic, or perhaps to the upper and most recent part of the Triassic formation; which of the two cannot be determined with certainty from the petrifactions hitherto found.

It is not impossible in Schonen that coal may be present under, or perhaps in, the calcareous formation; how it is related to it is not yet fully made out. At Höganäs, and in a few other places in the northwestern part of Schonen, coal was found as early as the seventeenth century, in small quantity to be sure; so in the earliest times extensive and thorough explorations of the coal-formation of these regions were begun. In the remaining part of Sweden, unfortunately, one cannot hope to meet with coal, since, with the exception of the regions named, the rocks which form the body of the country belong partly to the Laurentian or primitive formation, and partly to the Silurian system, while the later deposits, except a few metamorphic areas, belong exclusively to the latest geological age.

The iron-ores (magnetite and hematite or specular ore) which are usually met with elsewhere in Sweden, do not occur in Schonen; though it is by no means impossible that in searching for coal an argillaceous iron-ore* may be found, and in that case, if the coal of Schonen should prove suitable for the blast-furnace, this province would enter upon a flourishing iron-industry. If, on the other hand, no important deposit of argillaceous iron-ore be found, still the coal of Schonen, if on better acquaintance it justifies the hopes now placed in it, would be of essential value to the iron-manufacture of Sweden, although the considerable distance (about 530 kilometers) of that province from the great iron ore belt would essentially lessen its value.

* An inconsiderable deposit of such ore has been already discovered at Höganäs, which gave by the crucible-assay 39.5 per cent. of pig-iron with 0.13 per cent. of phosphorus.

In the future, be it as it may, Sweden is still pre-eminent in the working of her ores, both with the fuel which the forests and peat-bogs afford and that imported from other countries, for the refining of the iron produced.

131. *Transportation.*—The deposits of ore are by no means, as has been shown, uniformly distributed over the whole country; the densely wooded Norrland, for example, is wholly lacking, as far as is now known, in abundance of ore, with the exception of the province of Gefleborg, and the deposits at Gellivara, Lousavara, and a few other places in the northern part of the country. The same holds good also in a greater or less degree for many other forest-regions of the country.

It is, moreover, an undeniable truth that an important iron-industry cannot come into existence without convenient and ready means of intercourse, even in a country rich in coal. This must be the case to a much greater degree when the fuel necessary for the working of the ore must be brought from great distances, as here, where it consists entirely of forest-products. It is also a simple thing commonly to unite large deposits of coal with neighboring, or at least not very far distant, deposits of ore by means of railroads; but scattered forest-regions lying far from the mines are not so easily traversed by railways in order to bring the products of the former to those of the latter, and this is especially difficult in a thinly-populated country like Sweden. In this country, with an area of 445,000 square kilometers, or 8,079 square miles, of which 37,380 square kilometers, or 679 square miles, are water, according to the census of 1871 there were only 4,204,177 inhabitants, by far the greatest part of whom dwelt in the southern half of the country. Taking away the province of Gefleborg, the remaining part of Norrland, with an area of 243,700 square kilometers, or 4,425 square miles, has no more than 378,754 inhabitants. The southern and smaller part of Sweden, in 1871, had less than 3,820,000 inhabitants, and it is not surprising, therefore, that it was long feared that no railroad would be profitable here. Experience has shown that this fear was groundless, and very important railways have been finished during the last year.

At the end of 1871 there were 1,885 kilometers of railroad in operation; of these, however, 1,187 kilometers were main-trunk railways, and only occasionally touched the ore-districts, but, as main routes, aimed to unite certain important places as directly as possible. On the other hand, during the last year so many new railway-works were finished that at the end of the year 1872 about 2,100 kilometers of new railroads were in process of building, of which a very considerable part were mining railways.

Considering Sweden in a measure well provided with railways, still the iron-production, as regards quantity, cannot increase greatly in comparison with other countries, unless a hitherto unknown greater deposit of ore be discovered near the coal in Schonen; for only on this supposition can the expense of a production of ordinary iron in great quanti-

ties for the market of the world be possible in Sweden. Without such a discovery of ore in Schonen, Sweden must limit herself henceforth to the production of the so-called "quality-iron." The impossibility of founding an iron-manufacture which shall be important in the present time is much greater for Sweden, since there the second growth of the forest takes place much more slowly than in various other countries.

Since the forest-products, by greatly increased facilities of communication, obtain a higher value, the forests will be better cared for in the future, and the revenue obtained from them will be greater than now. In the more remote forest-districts the peasant has done nothing at all for the second growth of the wood; but even under the supposition of the fulfillment of what has just been said, it still remains impossible to build up a great iron-industry with charcoal alone. Each kilometer of forest in the neighborhood of our works, when it receives the best care, yields annually only 275 cubic meters of hard wood, while a square kilometer of forest, as ordinarily cared for by the Swedish peasant, if it has not been wasted, yields often not more than 105 cubic meters of hard wood annually, and from a solid mass of wood is obtained, according to the care in burning, 90 to 100, often only 60 to 70, per cent. in volume of coal. If 7.8 cubic meters of charcoal (coal-dust, &c., included) are reckoned to the ton of pig-iron, and if in the future as good care is bestowed upon the forests in general as is now given to a few forest-properties, a wood-area of 2.8 hectares will be required to supply the fuel necessary for the production of the quantity of iron mentioned.

132. *Use of English coke.*—There is a possibility of the amount of iron produced increasing considerably by the use of English coke for the blast-furnace, and then refining the pig-iron thus obtained by the Bessemer process. An important advantage over the English cannot be claimed for such a Bessemer product; it would be equal to it, however, and quite good enough for rails, &c. Such a production of pig-iron, based on English coke, has been seriously considered in Sweden, and could be accomplished much more easily than the project of exporting Swedish ore to England, for the production of pig-iron. This is partly because the freight to England is much higher than the return freight, and partly because fully one and a half times as great a weight of ore is necessary for the production of pig-iron as of good coke.

Although the old iron-works, with the help of coke from England, or possibly from Schonen, could compete with the English Bessemer product in a wider range than formerly, still it is not possible to produce in this way an article equal to the ordinary English in price, and it will remain none the less impossible, therefore, for the old manufacturing regions to develop an iron-production actually great as regards quantity. In this there is no obstacle to prevent the amount produced hitherto increasing considerably, after the completion of railroads now building, and also others; and it will first become possible through these railroads to leave the beaten way, that of producing bar-iron almost exclusively,

in order at the same time to make railroad-material, sheet-iron, &c., in greater quantity.

From what has been said already, the important advancement of the iron-production through railways must be evident; but the further proof of this matter is the fact that the forest-districts lying near the larger mines, which have been worked for a long time, through excessive cutting, have become in the lapse of time very much cut away, and the consequence is that the charcoal needed for the smelting of the ore must be brought from ever-increasing distances. With the aid of good communication, however, the amount of charcoal, which in the immediate neighborhood is beginning to fail, can not only be restored, but, by moderate cutting of the forest, far more coal than formerly can be made, since in many distant forest-regions the forest, until lately, has been wholly valueless,* and therefore has been very badly cared for, so that it has not yielded nearly the income which it might have done by judicious economy. In addition to this, it has been customary at distant saw-mills, with strange wastefulness, to burn, as useless, not only all the sawdust, but also all other rubbish, like bark, slabs, ends, &c.

It has been intimated above, and is shown more clearly by the following statistics, that the Swedish iron-works have, with few exceptions, produced till now almost exclusively bar-iron, or, in other words, merchant-iron. This circumstance may appear strange to a foreigner who is accustomed to seeing a ready ware, or at least partially-refined iron, produced at the works; but the chief cause of this, also, is to be sought for in the insufficient means of communication of the mining-districts. Pig-iron and bar-iron can be manufactured with profit in very small quantity, while this is not so much the case with railroad-material, since larger and more costly mills are necessary for that work, and they must have a considerable production in order to defray the first cost. For this it is indispensably necessary that considerable quantities of raw material can be brought to one point at a moderate price, which cannot be accomplished without good means of communication; in addition to which is the fact that a railway-connection is more necessary for iron-works which produce ready wares than for those which manufacture only merchant-iron, since the time of delivery is not usually so strongly limited for the latter as for the finished goods.

133. *Water-power.*—It is fortunate for the iron-manufacture of Sweden that the country is rich in water-power, small streams occurring in numberless quantity, on account of which all iron-works are located at water-falls. In the mining-districts also quantities of water occur which afford thousands of horse-power, and when these are connected by railroads with the mines and forest-regions they will afford the most suitable situations for greater iron-works, especially when great saw-

* In some regions, even in the last year, charcoal has sold for 1.75 francs per cubic meter, while at certain mines it brought 7 francs per cubic meter; and under the present favoring circumstances it costs in some places 14 to 17 francs per cubic meter.

mills, as is now and then the case, are already situated on the same fall, for the iron-works can then use the refuse of the saw-mills without extra cost for transportation. Many iron-works intended for the production of railroad-material and sheet-iron have been located in such places within the last two years, and it is the intention to have them completed at the same time with the railroads leading to them.

The demand of the world's market for Swedish bar-iron is in fact very limited, for it is much too good for most purposes, and its value can therefore be properly estimated only for certain uses, as for making the best steel and a few manufactured wares like wire, horse-nails, &c. A cheaper and poorer iron, on the other hand, answers for most purposes, and as inconsiderable as the amount of production of the Swedish iron has hitherto been, it has still been able to satisfy all demands under ordinary circumstances; therefore an increased production of so expensive a merchant-iron as the Swedish for many years would only bring about a lowering of the price of iron. If an essential increase of the Swedish iron-production is to bring an actual advantage, it is indispensably necessary that new works for the production of other kinds of iron than bar-iron be built; and this has, as has been remarked, actually happened, and also many of the old bar-iron works are beginning to change to the manufacture of Bessemer and railroad-iron. The other works, which remain as formerly, will, in consequence of this, be able to depend upon so much the more certain sale of their product in the future.

After these more general considerations we will now pass to a more definite statement of the condition in which the Swedish iron-manufacture is at present.

134. *Geological association of the iron-ores of Sweden.*—The iron-ores of Sweden are chiefly magnetite and hematite, which are classed together as mine-ores, to distinguish them from the bog-ores and limonite which also occur, but are worked only in the province of Småland.

The magnetic ores by no means always correspond to the formula Fe_3O_4, but with one molecule of sesquioxide can contain more or less than one of protoxide. Sometimes more or less hematite is intermingled, as in the ore from "Stora-Bispberg." Sometimes the magnetite is so mixed with hematite that it is hard to say to which class it belongs. In some mines, also, these two kinds of ore occur in beds side by side, as at Grängesberg and Dalkarlsberg; usually, however, they are separate, so that the same mine only affords one of the two ores.

The mine-ores, or the magnetite and hematite, belong to the Laurentian or primary formation, and never occur in with gangue or veinstone, but as actual beds or strata, which have the same strike and dip as the surrounding rocks. Many deposits of ore possess no great extent, but soon thin out; if, however, the strike of the rock is followed, sooner or later a new deposit is met with, and in this way the same bed of ore can often be followed for a myriameter. Other beds of ore, on the other

hand, often have a continuous extension in the direction of the strike, of many hundred meters, with a varying breadth.

The beds are sometimes sharply cut off and more or less displaced by transverse beds, so-called "skölar," of chlorite-slate, trap, or granite. Also, the thickness of the bed is very irregular, varying from an inconsiderable thickness to 30 or 40 meters. It is also very common to find the bed accompanied by several parallel strata of ore, which are separated by more or less barren rock.

The main mass of the solid rock of Sweden consists of granite and gneiss; considerable quantities of mica-slate are met with, and, in addition, hornblende-slate, "*helleflinta*," diorite, and granular limestone very often occur.

The iron-ores lie sometimes immediately in gneiss, as at Grängesberg, in the province of Kopparberg, and Norberg, in Westmanland; the gneiss itself is so poor in feldspar that it has been taken by some for mica-slate. When the ore lies in gneiss, the transition from barren rock to that containing ore is often very indistinct, and the ore then consists of a gneiss whose other constituents besides quartz are made up more or less of iron-ore. This is often the case with blood-stone, which consists usually of alternate layers of tolerably pure hematite and gneiss rich in quartz, and having iron-ore intersprinkled in it. These occur alternately, and the whole then consists of often many hundred parallel streaks of ore, between which stripes of quartz or gneiss lie. The smaller the latter are in proportion to the former, the richer the ore is.

Often these ore-deposits do not lie immediately in gneiss, but are surrounded by other rocks which themselves lie in gneiss. The envelope of the most considerable ore-beds consists of *helleflinta*, as at Dannemora, in the province of Upsala, or of a *helleflinta*-like gneiss, "eurite," as at Persberg, in Wermland. The ores are sometimes surrounded by mica-slate, as at Dalkarlsberg, in Örebro, and finally they are occasionally imbedded in granular limestone, as at Klackberge in Norbergs, in Westmanland, and at Långvik, in the province of Kopparberg. For the rest, the occurrence of lime in the ore-beds is very irregular. Finally, it is to be remarked that the ore-beds are often limited by peculiar mineral masses, so-called "skölar," in the hanging wall and in the foot-wall, which consist usually of chlorite and talc.

The dip of the Swedish ore-beds, like that of the surrounding rock, is, in consequence of the many flexures of the strata, very various; usually, however, it approaches more nearly the vertical than the horizontal plane. In addition to this side-dip, the ore-beds have very often a dip in the direction of the strike. As in the direction of the strike, so also sometimes downward, the beds thin out, but if the dip is followed down, a new mass of ore is usually met with sooner or later.

The blood-stone sometimes contains almost no other strata than quartz. Commonly, however, it is more or less mixed with other minerals, as pyroxene, hornblende, chlorite, epidote, garnet, and calx-spar.

This is still more the case with the magnetic ores, which are usually less acid, "dry," or rich in silica than hematite. Among the last named there are many which must be mixed with 30 per cent. or more of limestone in order to produce a bisilicate slag in the blast-furnace, to accomplish which, the magnetic ores seldom require more than 10 to 20 per cent. Often they need only a very small addition of limestone; and there are many ores which are self-fluxing, that is, they are associated with the above-named and other minerals in such proportions that they need no mixing with other ore, or with flux, for the blast-furnace. To these, among others, belong the Dannemora ore. Some ores are, finally, rich in lime, and are therefore mixed with the quartz-bearing "dry" ores; on account of which they are called "Gattirungssteine." These lime-bearing ores are, with few exceptions, magnetic, and often very manganiferous, like the ore from Långvik, which contains about 8 per cent. protoxide of manganese, and the magnetite from Klackberge, in Norberg, of which the Granrot ore contains 7 to 10 per cent. Mn O.

The iron richest in manganese, among those hitherto worked in Sweden, is the magnetic ore of the neighboring Svartberg, used at Schisshyttan, in the province of Kopparberg, for the production of spiegel iron. This ore contains 13 to 20 per cent. of protoxide of manganese, which is caused by the bed consisting for the most part of knebelite.* Among the very manganiferous iron-ores belongs the magnetite of the Penning-Grube, in the province of Gefleborg, containing 12 to 14 per cent. Mn O, and, likewise, an ore lately discovered in the Southern Hag. Grube, in Norberg, with over 30 per cent. Mn O.

The amount of iron in the Swedish ores varies between 30 and 70 per cent.; it is, however, usually about 45 or 50 per cent. Since lime-bearing ores are rarer than those with quartz, sometimes ores occurring in limestone, and having only 20 per cent. or less of iron, are worked; they are, however, always mixed with richer ores containing quartz before smelting.

Occasionally the ores are so rich in talc that not only limestone must be added before smelting, but also silica. Quartz alone is seldom used for this purpose, but ores containing quartz are added, of which there is seldom any lack.

The "mine-ores" contain usually very little phosphorus, and among those most free from phosphorus are the ores from Dannemora, in Upsala, with 0.003 per cent. of phosphorus, and from Persberg, in Wermland, with 0.004 to 0.005 per cent. phosphorus. Usually the amount of phosphorus varies between 0.005 and 0.05 per cent.; although there are some with a tenth of 1 per cent., as is the case with some of the richest iron-ores in the parish of Grangärdes and the neighborhood, and also with some of the peculiarly rich iron-ores high up in Norrbotten, as the Kerunawara and Gelliwara ores. In some of these ores as much as 1.5

* Knebelite, a silicate of iron and manganese, containing about 35 per cent. of oxide of manganese.—W. P. B.

per cent. of phosphorus is found. Ores which contain more than 0.15 per cent. of phosphorus have been heretofore only occasionally worked, and then only when mixed with those free from phosphorus. In most cases the phosphorus seems to come from intermixed apatite, and with reference to some of the Grängesberg ores, rich in this mineral, it has been proposed to treat them in the wet way, in order to change the apatite into superphosphate.

The ores most free from phosphorus are usually employed for the production of iron for steel-manufacture, and, since the most of the Swedish iron used in England is destined to serve as material for steel-manufacture, its value has hitherto depended mainly on the absence of phosphorus. As the Swedish iron has become more uniform and dense since the introduction of the Lancashire method, it has obtained a more extended use for the finer kinds of manufacture, and the iron produced with the greatest carefulness has latterly brought almost as high a price as the better kinds of cement-iron. The value of the iron intended for manufacturing purposes is not nearly so dependent on the absence of phosphorus as is the case with cement iron, but if there is only a few hundredths, or, at most, only 0.10 per cent. of phosphorus, then only the compactness and uniformity of the iron are considered, which properties are of most value for manufacturing purposes, and for this reason ores which contain only a few hundredths of a per cent. of phosphorus are most advantageously used for the production of this kind of iron.

Besides the ores most free from phosphorus, the manganiferous ores are advantageously employed for the production of cement-iron, and it is the main point to choose the most suitable ores for steel-production, while less care can be used in the refining process since compactness and uniformity are less necessary properties of the cement-iron. The contrary is the case in the production of manufacturing iron, since here these properties play the most important part, and the perfection of the same is dependent on the care which is employed in the refining; still it can by no means be said that an ore having still less phosphorus would not be of value for certain manufacturing purposes, and, in fact, ores much more nearly free from phosphorus are used in Sweden for the production of merchant-iron.

The mine-ores are almost always intermixed with more or less pyrite, and sometimes with other metallic sulphides, yet in most cases any considerable amount of sulphur in the ore can be removed by careful roasting. For this purpose shaft-furnaces, heated by the gas from the blast-furnace, are almost exclusively employed, and among the best of these are those constructed by E. Westman, in which so high a temperature may be obtained that the most difficultly fusible ores sinter together. These roasting-furnaces, which are shown in drawings and described in "*Ausführliches Handbuch der Eisenhüttenkunde von* J. Percy, *bearbeitet von* H. Wedding, 2 *Abtheilung*, p. 485," have, on account of their great superiority, supplanted the old gas-roasting furnaces, and now many ores which were before wholly useless can be employed.

Some iron-ores contain much titanium; yet the titanium is usually considered an unwelcome constituent of the ore, since it makes it so difficult of reduction, and the consumption of fuel in smelting titaniferous ores is so great. Among these ores the magnetite from Taberg, in the province Jönköping, deserves special mention, since it is different from the other Swedish ores in many respects. It is not, like most other iron-ores, collected together by itself, but the grains of ore occur so finely intersprinkled in a dark serpentine that it is impossible to separate them from it. This ore forms a whole mountain of 120 meters height and about 2,600 meters length, yet the amount of iron is not greater than about 30 per cent. Besides, this ore contains fully 6 per cent. of titanic acid and some vanadium, which was first discovered by Sefström in iron which was made directly from this ore.

More accurate information in regard to the composition of many Swedish iron-ores may be obtained from the tables of analyses:

135. *Production of iron-ore.*—In the year 1871 the yield of mine-ores was 647,119,000 kilograms, as follows:

In the province of Norrbotten, (Gelliwara,) 21,265 kilograms.
In the province of Wester-Norrland, (Ulfö,) 928,855 kilograms.
In the province of Jemtland, 15,736 kilograms.
In the province of Gefleborg, 22,444,697 kilograms,
viz, 13,235,200 kilograms from Nyäng, in the parish Thorsåker.
989,600 kilograms from the Erik-Ers-Grube, in the parish Thorsåker.
1,980,700 kilograms from Penning Grube, in the parish Thorsåker.
1,177,700 kilograms from the Sjöhag-Grube, in the parish Arsunda.
1,745,400 kilograms from the Rödäng-Grube, in the parish Ostra Fernebo.
In the province of Upsala, 33,132,273 kilograms,
viz, 21,405,500 kilograms from Dannemora, in the parishes Films and Dannemora.
1,003,700 kilograms from Ragnhild, in the parishes Films and Dannemora.
1,173,300 kilograms from Stenring, in the parish Morkarla.
3,991,200 kilograms from Ramhäll, (Hammarin,) in the parish Alunda.
3,143,800 kilograms from Sahlsta, in the parish Lena.
1,798,000 kilograms from Brunna, in the parish Lena.
In the province of Stockholm, 29,367,688 kilograms,
viz, 3,474,700 kilograms from Vigelsbo, in the parish Vahlö.
2,934,600 kilograms from the Sandgrube, in the parish Börstil.
5,146,100 kilograms from Skedika and Grind, in the parish Börstil.
1,385,600 kilograms from Björsta, in the parish Harg.

2,807,000 kilograms from the Slottsgrube, in the parish Söderby. Carl.
4,995,700 kilograms from Herräng, in the parish Häfverö.
7,842,200 kilograms from Utö, in the parish Österhanninge.

In the province Kopparberg, 178,046,656 kilograms,
viz, 1,020,200 kilograms from the Dvarnbacks-Gruben, in the parish Leksand.
21,142,200 kilograms from Vinkärn, in the parish Svärdsjö.
1,053,400 kilograms from the Sjö-Grube, in the parish Svärdsjö.
1,839,700 kilograms from Skinnaräng, in the parish Vika.
859,100 kilograms from Harmsarf, in the parish Kopparberg
3,100,400 kilograms from Hästberg, in the parish Stora Tuna.
9,055,200 kilograms from Romme, in the parish Stora Tuna.
2,674,400 kilograms from Bråfall, in the parish Stora Tuna.
12,870,800 kilograms from Stora-Bispberg, in the parish Säter.
1,080,400 kilograms from Vestra-Bispberg, in the parish Säter.
1,531,600 kilograms from the Tägt-Grube, in the parish Säter.
3,469,400 kilograms from Knappkärn, in the parish Hedemora.
1,359,900 kilograms from the Öster-Grube, in the parish Gustaf.
12,554,500 kilograms from Rellingsberg, in the parish Husby.
2,505,900 kilograms from Rullshyttan, in the parish Garpenberg.
1,324,400 kilograms from Långvik, in the parish Garpenberg.
2,683,000 kilograms from Svartfjäll, in the parish Garpenberg.
24,859,200 kilograms from Ormberg, in the parish Grangärde.
5,086,600 kilograms from Grängesberg, in the parish Grangärde.
4,629,000 kilograms from Risberg, in the parish Grangärde.
1,605,100 kilograms from Fäbobacken, in the parish Grangärde.
7,820,600 kilograms from Finnäs, in the parish Ludvika.
2,129,200 kilograms from Fredmundberg, in the parish Ludvika.
7,598,000 kilograms from Gräsberg, in the parish Ludvika.
9,318,500 kilograms from Håksberg, in the parish Ludvika.
4,338,100 kilograms from Östanberg, in the parish Norrbärke.
7,360,400 kilograms from Nyberg, in the parish Norrbärke.
3,282,300 kilograms from Gesberg, in the parish Norrbärke.
4,999,600 kilograms from Svartberg, Marnäs, in the parish Norrbärke.
7,481,900 kilograms from the Svartberg, Svart-Grube, in the parish Norrbärke.
884,800 kilograms from Siksjöberg, in the parish Norrbärke.
1,275,900 kilograms from the Slät-Grube, in the parish Norrbärke.
2,344,500 kilograms from Hilläng, in the parish Norrbärke.

In the province of Westmanland, 92,225,667 kilograms,
viz, 27,716,600 kilograms from Risberg, in the parish Norberg.
16,112,500 kilograms from Morberg, in the parish Norberg.
20,138,500 kilograms from Klackberg, in the parish Norberg.

6,044,000 kilograms from Uddevalla, in the parish Norberg.
1,457,800 kilograms from the Badstugu-Grube, in the parish Norberg.
948,400 kilograms from the Norr-Grube, in the parish Norberg.
4,191,300 kilograms from the Ny-Grube, in the parish Norberg.
2,750,800 kilograms from the Finn-Grube, in the parish Skinnskatteberg.
3,585,300 kilograms from Bastnäs, in the parish Skinnskatteberg.
1,003,500 kilograms from the Kulle-Grube, in the parish Skinnskatteberg.
2,216,700 kilograms from the Backe-Grube, in the parish Skinnskatteberg.
3,431,500 kilograms from Lugndal and Springan, in the parish Sala.
1,264,400 kilograms from Åby, in the parish Sala.

In the province of Öubro, 135,690,051 kilograms,

viz, 4,014,000 kilograms from Lomberg, in the parish Nya Kopparberg.
7,431,900 kilograms from Svartvik, in the parish Nya Kopparberg.
995,200 kilograms from the Limbergs, Moss-Grube, in the parish Nya Kopparberg.
7,065,900 kilograms from Strossa, in the parish Ramsberg.
2,479,700 kilograms from Blanka and the Kärr-Gube, in the parish Ramsberg.
14,290,100 kilograms from Stripa, in the parish Linde.
2,505,400 kilograms from Grönvold, in the parish Linde.
2,598,400 kilograms from Bredsjö, in the parish Hjulsjö.
2,114,300 kilograms from Ånnenäs in the parish Hjulsjö.
1,410,500 kilograms from the Stora Björnhöjde-Grube, in the parish Hjulsjö.
3,408,400 kilograms from Högborn, in the parish Grythytte.
14,057,400 kilograms from Dalkarlsberg, in the parish Nora.
3,522,300 kilograms from Vikers, in the parish Nora.
8,467,700 kilograms from Pershyttan, in the parish Nora.
27,676,000 kilograms from Striberg, in the parish Nora.
6,592,100 kilograms from Ryngshyttan, in the parish Nora.
8,141,100 kilograms from Klacka, in the parish Nora.
2,792,500 kilograms from Fogdehyttan, in the parish Nora.
2,576,900 kilograms from Hvilare, in the parish Nora.
2,926,100 kilograms from Slotterberg, in the parish Jernboås.
3,423,700 kilograms from Finnshyttan, in the parish Jernboås.

In the province Wermland, 121,252,392 kilograms,

viz, 13,487,100 kilograms from Nordmark, in the parish Nordmark.

11,560,100 kilograms from Taberg, in the parish Nordmark.
5,382,200 kilograms from Finnmossan, in the parish Nordmark.
8,327,800 kilograms from the Eng-Grube, in the parish Fermbo.
52,972,000 kilograms from Persberg and Yugshyttan, in the parish Fermbo.
5,886,200 kilograms from Långban, in the parish Fermbo.
3,330,300 kilograms from Kroppa, in the parish Kroppa.

In the province Södermanland, 19,231,386 kilograms,
viz, 4,529,400 kilograms from Högsjö and Staf, in the parish Floda.
3,412,600 kilograms from Sofia, Wilhelmina, and Mosstorp, in the parish Sköldinge.
2,564,700 kilograms from Kantorp, in the parish Sköldinge.
1,275,900 kilograms from Porthål, in the parish Gåsinge.
3,621,900 kilograms from Förola, in the parish Svärtuna.
1,833,000 kilograms from Gillinge, in the parish Svärtuna.

In the province Ostgothland, (Natorp, in the parish Skällsvik,) 4,450,169 kilograms.

In the province Calmar, 382,770 kilograms.

In the province Jönköping, 9,910,128 kilograms, of which 9,457,300 kilograms were from Taberg, in the parish Måusarp.

In the province Kronsberg, 19,266 kilograms.

In the iron-mines, there were employed in the year 1871 4,191 steady workmen, 436 periodical workmen, 312 women and children—total, 4,939 persons.

136. *Methods and costs of mining.*—The miners work by contract, and in a few places are paid according to the amount of ore obtained, but usually according to the length of drift excavated. Sometimes these two methods are combined in such a way that the owners of the mine pay according to the amount of ore obtained, and the money is divided among the workmen according to the length of each drift. Usually the miners earn from 2 to 4 francs a day; sometimes, under favorable circumstances, still more. Usually it is very difficult to fix the income of the miners accurately, for most of them enjoy certain advantages in addition to their mere wages, like free lodgings and firing, land for potatoes, fodder for a cow, &c.; only the workmen which at present have about 4 francs are without these advantages.

Usually the same workman manages the drill as well as the hammer, only in a few places does he make use of a special striker. The drifts are usually only 24 millimeters wide, and cost for drilling downward 1 to 2.5 francs per meter, according as the workman, in addition to his mere wages, enjoys other advantages or not; for drilling upward—"dry-boring"—it costs twice as much. Drill and hammer are now always steel. For blasting, either gunpowder, dynamite, or "ammonia-gunpowder," which latter consists of a mixture of about 20 per cent. nitro-glycerine with nitrate or picrate of ammonia and charcoal-powder, is used. Pur nitro-glycerine has been used, and at some mines is considered the best

blasting agent; the many accidents, however, which the latter has occasioned have had such an influence on its use that it is almost prohibited.

The amount of work done by each miner is naturally very various, since it depends partly on the degree of hardness of the ore, or more properly the bed, partly on the kind of work and wages, and, finally, on the blasting agents used, which must be determined by the character of the mine. The following numbers may be taken as the average: Usually 1.5 to 2 meters, sometimes 3 meters, are excavated, per day and man; in drilling upward, however, only about 1 meter, and 0.5 to 1.6 cubic meters, or about 1,300 to 3,800 kilograms of loose ore are obtained. Per kilogram of dynamite and ammonia-powder, 10 to 16 tons of loose ore are obtained, and per kilogram of gunpowder, 5 to 6 tons. The cost for the ore brought up and separated amounts to from 2.9 to 16 francs per ton.

Concerning the method of mining, that of mining by levels is most common. A shaft is sunk through the loose layers of earth possibly present, and deep enough into the ore-bed that the part of it passed through will form a safe roof, if side-galleries are to be established. The main shaft is continued downward, if the ore is to be taken out by levels, (*Strossenbaus*,) leaving, however, the necessary supports or piers to retain the walls of the mine.

The space excavated is usually left open and empty; but in a few mines, whose walls cannot be held by supports or piers, but must be strongly timbered on account of cracks and brittle places, they have begun to fill up the space with dead-rock, and then take out the ore from the top of the level, (*Firstenbau.*)

The last-named method is unnecessary in most of the Swedish mines on account of the solidity and strength of the rock, but it will probably come into use in the future more than at present, since many mines have become unsafe through lapse of time. A circumstance that considerably hinders the use of this method in Sweden lies in the fact that the amount of dead-rock necessary for filling up is almost never found in the mine, since about half of the whole mass of rock taken out is requisite.

When the ore is raised from the mine vertically, either wooden buckets bound with iron, or those made of Bessemer steel, are employed, which hold 0.165 cubic meter, or about 425 kilograms, of ore, and which are provided with wire-ropes for hoisting. When the ore is brought out at an angle, on the other hand, usually tramways or railways with little cars are used, which likewise are attached to wire-ropes. The water is raised by means of suction and lifting pumps, arranged under each other, each of which is nine meters long; in deeper mines, however, the more suitable force-pumps are found in use, with a forcing-power of about 180 meters. The greatest vertical depth of any of the Swedish iron-mines at present is 230 meters.

In the smaller mines one engine sometimes raises both the ore and the water; commonly, however, different motors are used for these purposes. Since Sweden, as has been remarked, abounds in rivers, at most of the mines water-power occurs, and in order to transmit the power from the water-fall to the mine, sometimes wooden shafts, sometimes ropes, are used. Such shafts, which sometimes have a length of nearly 3,000 meters, are very common for the transmission of power to the pumps, but are seldom used for raising the ore; when the distance to the nearest water-fall is too great for the employment of ropes, for the latter purpose steam-power is used. Also for pumping water the latter power must sometimes be employed, and there were in the year 1871, among all the mines of Sweden, fifty-six steam-engines in use, most of which, however, had only ten to sixteen horse-power.

That both the number and the power of the engines must be increased is a natural consequence of the increasing depth of the mines, and also of the increasing demand for ore; for a water-power which is sufficient to raise ore from an inconsiderable depth will be inadequate for greater quantities of ore and greater depths.

Owing to the above-mentioned causes, the annual consumption of ore has been so small in proportion to the richness of Sweden in ore, that enough could be obtained without difficulty, usually, and the price of ore at most of the mines has been so small (6.50 to 9.80 francs per ton) that, with few exceptions, the aim of the proprietors of the mines has been to supply the small amount annually required with the least possible expense. Such a method of procedure is in most cases irreconcilable with a rational system of mining, and it is doubtful if such a system can ever be possible so long as the same ore-bed, standing nearly vertical, is not worked by one single company, but belongs to several different owners, each of whom works his own shaft, and who may easily come into collision with each other down below the surface. Besides, the available water-power in many great mining-districts is not sufficient for raising immense quantities of ore; it stands to reason, however, that a much greater effect could be produced with it if the mines stood in connection with each other, so that the raising of the ore and the water could be concentrated in a few single shafts, instead of every separate shaft having its own hoisting and pumping apparatus, as is now often the case.

It is not strange, therefore, that the prospects of a better future for the iron-industry, opened by the high price of iron at present, and still more by the railroads in process of construction, have caused a considerable rise in the price of iron-ores, which are now sold for 24 to 30 francs and more per ton; in addition to this, it is to be hoped that increased value of the mines will lead to a more rational mining-system than that hitherto in use, and many signs indicate that this hope will soon be fulfilled.

137. Bog-iron ore and limonite.—The bog-ores, which consist of

hydrated sesquioxide, are formations of the latest time, and are continually forming now. They occur in many provinces, and formerly were used for the direct production of wrought iron. They occur in the greatest quantity in the province of Småland, and are worked almost alone in this province; since they usually contain several tenths of a per cent. of phosphorus, cast iron only is made from them.

The bog-ores, which, according to their appearance, are called "Pulver-," "Perlen-," "Pfenning-," or "Kuchen-ore," form beds 0.75 meter thick, and occur usually in marshy places a short distance from the shores of the lakes. After the lakes are covered with ice they are taken out with long-handled shovels and steel sieves. The deposit gradually forms again, so that in about twenty years a new bed has formed in the same place. Owing to the necessity of obtaining the ore in the winter, this can never be of very great importance.

In the year 1871 15,769,444 kilograms of bog-ores were obtained, as follows: 127,590 kilograms in the province of Skaraborg; 555,527 kilograms in the province of Calmar; 8,911,864 kilograms in the province of Jönköping; and 6,174,463 in the province of Kronoberg.

138. PRODUCTION OF PIG-IRON.—As early as 1830 there was a "stückofen" or high bloomary furnace in operation in the province of Jemtland, but since this time, a few experiments excepted, wrought iron has not been produced directly from the ore; but the iron-ores are first reduced to pig-iron in a cupola-furnace.

Formerly the cupola-furnaces had but 1 tuyere and were 9 meters high; latterly, most of them are increased in height, and are provided with 2 to 4 tuyeres, and the newly-built furnaces have a height of from 12 to 16 meters. The height of the cupola-furnaces at present, therefore, varies between 9 and 16 meters, and their internal diameter between 1.5 and 1.9 meters at the top; 2 and 2.9 meters at the belly; 0.8 and 1.4 between the tuyeres. The internal capacity of the furnace-shafts varies between 23 and 90 cubic meters. Usually two, sometimes three or four, tuyeres are used; in a few furnaces there is still only one tuyere. The diameter of the tuyeres is usually, in two-tuyere furnaces, between 47 and 60 millimeters. The pressure of the blast varies between 24 and 90 millimeters of mercury; it is generally 36 to 60 millimeters. Blasts ranging from cold air up to air at 400° C. are used; in general, however, it is scarcely 200° C.

Charcoal is used almost exclusively as fuel in the cupola-furnaces. It is mixed with wood in a few furnaces, especially in Småland, 0.21 cubic meter of oak wood corresponding to about 1 Swedish ton, or 0.165 cubic meter of pine charcoal; at most, every third ton of coal is replaced by wood in this way. At Schisshyttan, where speigel iron is produced, Mr. Keiller has lately begun to employ wood in greater quantities, and the furnace has been built up to 17.8 meters for the purpose, the upper 3.5 meters of which form an apparatus for converting wood into charcoal, which is heated by a part of the gases, which are very rich under

such proportions. Besides wood, coke and some charcoal are used, and the blast is intended to have a pressure of 118 millimeters of mercury, and a temperature of about 500° C. In a few spiegel-iron furnaces charcoal mixed with English coke is used, without the addition of wood.

The coal is made almost entirely from pine and fir, and every ton (0.165 cubic meter) contains about 21.3 kilograms of actual carbon. The consumption of coal varies between 5 and 8 cubic meters per ton of pig-iron. In the furnaces, however, which work the very poor and titaniferous ore from Taberg in Småland, it rises to 15.5 cubic meters. The ordinary consumption of coal is 5.8 to 6.6 cubic meters per ton of pig-iron, or, when reckoned by weight, 75 to 85 kilograms clear carbon to 100 kilograms pig-iron.

The ore is roasted in pieces the size of one's fist, or twice as large, and then crushed between rollers or in a Blake stone-crusher to the size of a walnut. The charges of ore are made, according to the size of the furnace, of 6 to 10 tons, or 0.99 to 1.65 cubic meters coal, and great care is used in charging, so that most of the ore lies where the most gas comes up, which is usually along the walls. In proportion to a cubic meter of coal, more of a poor ore can be charged than of a similar but richer ore; yet not enough of the poor ore can be added so that the consumption of fuel per kilogram of pig-iron produced will not be greater than for the rich ore. If the unusual proportions which the ore from Taberg requires are excepted, the charges give commonly 40 to 50 per cent. of pig-iron, and per cubic meter of coal 260 to 450 kilograms of ore and limestone are charged. These differences are by no means occasioned by the amount of iron in the charge, but also by the ease or difficulty of reducing the ore, so that usually considerably more of the hematite (blood-stone) can be charged than of the magnetite, which is not so easily reduced. In addition to this, the charge of ore per cubic meter of coal can be greater, and therefore the consumption of fuel per ton of iron less, in the larger furnaces than in the small ones; and naturally in a furnace in which a higher temperature of blast is employed more ore can be added. Finally, it is to be noticed that the carbonization in different places is conducted with very different carefulness, and good coal can naturally bear more ore than loose and brittle coal.

According to the capacity of the furnace, the descent of the charge is more rapid in the smaller furnaces than in the more capacious ones. In the largest furnaces, only a small change in the state of the contents of the shaft takes place in twenty-four hours, while in the smaller ones they are renewed from two to two and a half times. The absolute change of the charge, or the number of cubic meters of coal consumed in the unit of time, is in each case greater in the more spacious than in the smaller furnaces. In the smallest furnaces, weekly, 30 to 64 tons, in the medium-sized, 64 to 85, and in the largest, 85 to 130 English tons of pig-iron are produced.

The furnace-gas is generally employed for roasting the ore and heating the blast, and in such iron-works as have a lack of water-power, it serves also for heating the steam-boiler. If a Westman roasting-furnace is used, and a moderately high temperature of blast is required, then the gas is only sufficient for the two first-mentioned purposes. The whole of the gas is not available, but a part escapes through the top of the furnace, which is usually open. The gas which is used is taken out either by cylinders reaching 2.3 to 3 meters below the top, or through three or four gas-conductors, opening about a third of the height of the furnace, or 3.5 to 5 meters below the top. A few furnaces are provided with covers, but from the way in which the charging is managed, they remain open a third of the time. Only at Schisshyttan is a mouth closed according to the bell-and hopper principle employed.

Most of the pig is destined for the "hearth-finery" according to the so-called Lancashire method, and for this purpose an iron, poor in silicon and without adhering sand, is desired; so the ordinary pig-iron is not cast in sand-molds, but in forms in which it receives the shape of broader and flatter pigs. Such iron is usually desired mottled, and for that purpose the charges are so mixed as to give about a bisilicate slag. For the production of iron destined for the manufacture of bar-iron, more basic mixtures are desired, and therefore greater quantities of limestone and manganiferous ores are employed than in the charging for merchant-iron, which can often be somewhat acid.

The pig-iron destined for the Bessemer fining is usually blown gray, nevertheless, however, with more basic charges than the above-mentioned or Lancashire pig-iron.

In the district of Dannemora an almost white iron, with small gray spots like hail-stones, which is cast in sand in the form of pigs of 4 to 6 meters in length, is desired for the Wallon fining process. The charges used in the production of this iron are the most basic of any in Sweden, with the exception of those required for spiegel iron. They approach much more nearly the singulo-silicate than the bisilicate, but no limestone is added to them, because the Dannemora ores are so rich in lime and magnesia that it happens that with the low temperature of the blast employed at Dannemora, (from unwarmed to 100° C.,) the smelting cannot be accomplished without the addition of silica.

Ordinary mottled Swedish pig for hearth-fining contains, generally, about 4 per cent. carbon, 0.1 to 0.4 per cent. silica, and 0.01 to 0.03 per cent. sulphur, and also 0.01 to 0.05 per cent., sometimes even 0.15 per cent., phosphorus. The amount of silicon in the Bessemer pig is usually about 1 per cent.; in a few places, however, it is only 0.7 per cent.

At a few furnaces, as at Schisshyttan and Finnsbo, manganiferous spiegel iron is produced. These two furnaces lie in the province of Kopparberg, and work the Svartberg ores containing knebelite. The charges are made as basic as possible, and for the production of a high

temperature the charcoal is mixed with some coke. The spiegel from Schisshyttan contains occasionally 17 per cent. of manganese.

Pig-iron for ordinary castings is generally made from trisilicate charges, but this is not very important, for cast iron is imported from England and Scotland. On the other hand, at a few furnaces, a cast iron is produced superior on account of its great hardness, as at Finspong, where the cast iron is used for cannons, projectiles, car-wheels, &c., and at Ankarsrum, where the cast iron is used for projectiles and car-axles.

Finally pig-iron is also produced for malleable castings; for example at Åker and at Kihlafors.

The blast-furnace slag serves quite often as a building-material, for which purpose it is cast in iron molds, and it is very common to employ slag-bricks for the outer wall both of the cupola-furnace and the roasting-furnace; sometimes, indeed, the whole furnace-shaft is built of this material.

139. MEANS AND METHODS OF TRANSPORTATION.—In consequence of the difficulty of bringing together to one place great quantities of charcoal and ore, there have been at one place only, namely, Finspong, two furnaces till within the last year; and at most of the iron-works the material has not been sufficient to maintain the single furnaces in uninterrupted activity for the whole year. All the material must be brought to the majority of the Swedish furnaces on sleds, and, therefore, the blowing does not begin till sleighing comes. The duration of the campaign depends in great measure upon the character of the winter; for the better and longer the sleighing is, the more material can be brought. However, it has been possible at only a few places to obtain during the winter enough coal and ore to continue the campaign till sleighing begins again the next year, but it ceases usually about the beginning or middle of the following summer, and then the furnace-hands are employed about the harvest, &c. There are examples, however, of the campaign continuing uninterruptedly for six years, as at Borgvik, in Wermland.

At a few of the old iron-works, which have better communication, during the last year new furnaces have been erected beside the old ones, so that now not only at Finspong are there two furnaces, but also at Westanfors, Sandviken, Hofors, Dalkarlshyttan, and Forsbacka. Besides, at a few others of the older works a second furnace is being built, and at some of the greater Bessemer plants, determined upon during the last year, though not yet completed, it is the plan to erect three or four blast-furnaces.

Through improved means of communication the manufacture of pig-iron is continually becoming more independent of the character of the winter; yet good and not too short sleighing will always be the chief requisite for a considerable iron-production, for the charcoal-heaps in the interior of the forest are usually attainable only when the rivers and lakes are covered with ice and the snow has made the trackless wilder-

ness passable. Therefore, in most cases the coal can be brought to the railroads or other ways of communication only during this time.

For man, horse, and cart, the price is 3.5 to 7 francs a day; under the present favorable conjunction, however, 12 francs and even more. For further transport, it costs per kilometer for 1 ton 20 to 60 centimes, while the freight for ore, coal, and iron on the government railways is for 1 Swedish mile = 1.441 geographical miles, or 10.686 kilometers, 1.30 francs per ton;* 10 Swedish miles, 6.53 francs per ton; 20 Swedish miles, 10.45 francs per ton; 30 Swedish miles, 14.37 francs per ton; 40 Swedish miles, 16.98 francs per ton; 50 Swedish miles, 20.58 francs per ton; 60 Swedish miles, 24.17 francs per ton; 70 Swedish miles, 27.76 francs per ton; but when the distance is more than twenty miles, often a discount of 20 per cent. is allowed.

The furnace-hands, like the miners, often have lodgings and other advantages, and their mere wages are less, therefore, the greater the former are; they are paid by contract, usually 2 to 5 francs for the furnace-master and 1.75 to 2.75 francs for the other hands.

The cost of working is from 4.90 to 6.50 francs per ton of pig-iron, including the roasting and breaking of the ore.

NUMBER OF FURNACES AND PRODUCTION.—During the year 1871, there were 207 blast-furnaces, which together were in operation 37,471 days; 293,116,971 kilograms of iron in pigs, 5,810,489 kilograms of cast ware, or in all 298,917,460 kilograms of iron were produced, and at the works themselves 3,812 hands were employed.

140. WROUGHT IRON AND STEEL.—The fining method most generally used in Sweden is that kind of hearth-fining commonly called the Lancashire method. It is a process which is carried on in small covered hearths, and the bloom-iron obtained from the same is afterward welded in separate furnaces. The hearths have usually two tuyeres, someimes, however, only one, which stand opposite each other, and each opening in the two-tuyered hearth is about 3.5 square centimeters in size. The pressure of blast is about 80 millimeters of mercury, and the temperature of the same is between 100 and 200° C. For each bloom 90 kilograms of pig-iron are usually added, but this number varies in different places between 68 and 128 kilograms. Two to three men, who alternate with others, are constantly employed in the working, which is continued day and night for six days in the week, in which same in each hearth 6,800 to 12,800 kilograms of bloom-iron are produced, with a loss of about 13 per cent. of pig-iron, and a consumption of fuel of 4.6 to 6.6 cubic meters of coal, that is, after reception in the coal-shed, per ton of bloom-iron.

The blooms in the larger iron-works are compressed under trip-hammers of 3,400 to 4,300 kilograms' weight, which are entirely of cast iron; in the smaller works, on the other hand, they are drawn under wooden-handled breast-hammers of only 850 kilograms' weight, or sometimes under steam-hammers of 650 to 1,300 kilograms' weight.

* 1 ton here, as elsewhere in this memoir, generally is equal to 1,000 kilograms.

In many places lately rolls have been set up, with the aid of which the compressed bloom is rolled out, without reheating, into bars, partly for refined-iron manufacture and partly for the production of cast steel. Usually, however, the blooms compressed under the hammer are allowed to get completely cold before they are heated to welding-heat in separate ovens, in order to draw them finally under the hammer or through the rolls. A piling-up does not take place except with the cut-off ends and waste iron, but each bloom is welded by itself, and this welding occurs in the smallest works, sometimes in forging-fires, but usually in gas furnaces. It is to be noticed here that the working of the forges is generally continuous, so to speak, for it does not happen, as in other countries, that the furnace is for once filled up with blooms, and then left to itself till all the blooms together have reached a welding-heat, but the furnace is very long, and the blooms are introduced cold into the end farthest from the fire-hearth, and are pushed forward by degrees toward the warmer part of the furnace, as other blooms are taken out at a welding-heat, till they are brought near the fire-bridge, where they obtain a full welding-heat and are finally taken out. When a welding-hot bloom, therefore, is taken out, all the others are pushed forward, and the space at the cooler end of the furnace is filled with a new cold bloom, and so it goes on uninterruptedly.

As fuel in the gas-furnaces, in a few places, charcoal alone is used; usually, however, it is mixed with mineral coal, peat, or wood; sometimes, also, one of these three last-named fuels is used. The furnaces are different in their construction, according to the fuel for which they are intended; most of them are variations of the old Ekman furnace; lately they have given place somewhat to the Lundin welding-furnaces. They are Siemens regenerating-furnaces in combination with condensers to remove the water present in the fuel, which in these furnaces consists exclusively of air-dried saw-dust, wood, or peat.

The action of the welding-furnace is very different, according as the bloom is drawn by means of the hammer or rolls, for in the latter case the whole bloom is heated and drawn at once, while in the former first one end is drawn and then, after reheating, the other. A welding-furnace, with apparatus for drawing by means of hammers, turns out weekly 25,500 to 55,300 kilograms, while one with rolls in the same time will produce 51,000 to 85,000 kilograms. The consumption of fuel in a welding-furnace per ton of bar-iron is essentially less in the rolling than in the hammering process, and generally varies between 1.9 and 3.7 cubic meters charcoal, or 0.25 to 0.6 cubic meters hard coal. In the Lundin welding-furnace, on the other hand, it is usually 1.8 to 2.5 cubic meters wood, or 3 to 4.3 cubic meters of air-dried peat, or about 6.8 cubic meters of saw-dust, per ton of bar-iron.

Finally, the loss of iron through the welding is less in rolling than in hammering; in the former it is about 9 per cent., and in the latter 12 per cent. of the weight of the blooms.

Rolling-mills are naturally unsuitable for small iron-works, which, however, can derive advantage from them by discontinuing their old hammering-process, and instead, producing only blooms which can be worked by one rolling-mill common to several such fining-mills. In this way the rolling-mill of Smidjebacken up to the year 1871 had rolled the most, but in that year, however, Bofors had the greatest production, namely, 6,128,150 kilograms of bar and refined iron.

Besides the Lancashire method, the so-called Franche-Comté finery-process is employed, especially in small iron-works in whose neighborhood there is no rolling-mill. In the manner in which it is here conducted it is similar to the first, only the welding of the blooms occurs in the same hearth. In this process the loss is somewhat less than in the Lancashire method, in which the welding takes place in separate furnaces; on the other hand, the production is not so great, being only 3,800 to 4,300 kilograms of bar-iron weekly for each hearth. The great fault is that the consumption of coal is so great, it being about 9.7 cubic meters of charcoal per ton of bar-iron, sometimes even rising to 11.6 cubic meters or more, which will soon cause the discontinuance of this method, when improved communication shall have increased the value of charcoal in the remote districts.

In the Dannemora district the old Wallon process is employed, in which two hearths are usually worked together in such a way that the bloom produced in one is welded in the other, and then drawn under the hammer. The two hearths afford 8,500 to 10,700, sometimes even 12,700, kilograms of bar-iron weekly, with a consumption of charcoal of from 19 to 23, sometimes, however, only 15, cubic meters per ton.

In a few places, finally, other fining methods are employed, but those named are the only ones which now have any importance for Sweden. Among them all, the Lancashire method affords the most uniform and densest iron, which again depends upon the control which a well-regulated furnace has over the hands. If the welding is done in a hearth-furnace, it is much easier for the smith to draw a bar free from flaws on the outside from a bloom which is not uniform, than when the welding-furnace is used, for there the different parts of the bloom are exposed to a more uniform heating. Since uniformity and compactness are chief requisites of a good merchant-iron, naturally the Lancashire method is the most suitable fining-process for the production of such iron.

Of the Wallon iron it may be said that it is characterized by its not being uniform, or by a mixture of weak and hard, almost steel-like, iron. It is used exclusively for steel-production, and then the non-uniformity is not very injurious, while the value is really determined by the "body" caused by the properties of the ore used for the production of the iron. Indeed, it appears as if the non-uniformity of the Wallon iron was a good property in the eyes of the English steel-manufacturers, since they are opposed to changing this method. If the real cause of

this is sought for, it must be found in the fact that the hard, steely parts shorten somewhat the time required to burn this iron to steel.

The mere wages of the forgers are governed by the amount produced, and the contract is so drawn up that only one, (the master,) or more often two, (the master and his helper, each of whom oversees his work,) are responsible for the result, and must pay fines when the loss of iron or consumption of coal exceeds certain limits; on the other hand, however, they obtain special pay for coal saved and higher wages for the so-called "overiron" than for the iron which they must produce from a certain amount of pig-iron, according to contract. In addition to various advantages, the master and his helper have usually 2,100 francs annually, but they must pay their own help.

In the Lanschire method, the cost of working amounts to 10 to 13 francs per ton of bloom-iron, and for the welding and drawing, to about 10 to 16 francs per ton of bar-iron, less for rolling, and more for hammering.

During the year 1871, in the whole country, with 827 active hearths, 187,791,642 kilograms of bar and refined iron were produced, and 6,073 workmen were employed.

141. *The pudding-process* is employed at only a few iron-works which manufacture their own iron, namely: At Motala, Surahammar, Nyby, Gunnebo, and Kallinge. The fuel used in the pudding-furnace is usually English mineral coal, only at Surahammar and Nyby wood is employed.

At Motala, in a few puddling-furnaces a weak blast is used under the grate, and before it is brought into the ash-pit its temperature is raised by being conducted around the furnace-walls and under the bottom. By measure the furnaces use about 0.95 cubic meters, or 730 kilograms, of mineral coal per ton of puddled-iron; on the average, the consumption of coal, after receiving into the coal-shed, is fully 1.2 cubic meters, or 960 kilograms, per ton of bloom-iron, about 17 tons of which are produced weekly from each furnace. Surahammar uses about 6 cubic meters of air-dried pine wood per ton of puddled iron.

At Motala experiments are being tried with Dank's self-acting puddling-furnace. As the puddling has hitherto been conducted, the cost of working has been about 11 francs per ton of bloom-iron.

The welding-furnaces at Motala are exclusively heated with mineral coal, and most of them are provided with blast according to Whittenström's construction. The Wittenström welding-furnace, which is used elsewhere in some other iron-works, is in fact only a modification of the Ekman furnace, but not the above mentioned with the so-called "coal-tower," but that for wood. The main difference is that the fire-hearth of the last-named furnace has no grate, like the Wittenström, and that the blast, which in the Ekman furnace is introduced through the end-wall of the fire-hearth, in the other enters under the grate.

142. *Bessemer process.*—The Bessemer process has been used in Sweden since its beginning, but in the year 1871 not more than 8,038,-

254 kilograms of Bessemer metal were produced, and, although this process seems very suitable for Sweden, since, on the one hand, most of the Swedish ores are well adapted for it, and, on the other, the consumption of fuel for the metal produced by this process is only about half as great as for the Lancashire iron, still the Bessemer process has not, till of late years, received a general recognition. The main cause of this lies, doubtless, in the fact that this method requires such costly apparatus, and on this account is not suitable for iron-works with a small production; in addition, the Bessemer process is not well adapted for the production of bar-iron, but requires the manufacturing or improving of the ingots produced for ready wares. The last-named circumstance should be no hinderance to the spread of the Bessemer process, for a considerable increase of the Swedish iron-industry can only be obtained by producing some other kinds of iron than bar-iron, for the demand for this in the world's market is usually very limited. In the last year Sweden has sold to foreign countries almost no other kinds of iron than bar-iron and refined steel, and it is therefore necessary, for the introduction of the Bessemer process, to create a new market, which naturally hinders the spread of this process. All the large iron-works completed lately, lying on the projected railways, are intended for the Bessemer manufacture, and, in addition, in the year 1872, four Bessemer works, Forsbacka, Abäckshyttan, Långshyttan, and Iggesund, have been completed, and two others, Långbanshyttan and Ulfshyttan, nearly so, and, finally, many iron-works which have hitherto used the Lancashire method are erecting Bessemer works.

In the year 1871 there were seven Bessemer works in operation, but the production at three of them, which have small upright furnaces, was very slight, from all of them not amounting to more than 397,740 kilograms. The rest, or 7,640,514 kilograms, was produced at Sandviken, Westanfors, Svartnäs, and Bäcka, where the English movable furnaces are used. All the Bessemer works erected during the previous year have movable furnaces, and it is very improbable that hereafter any stationary Bessemer furnaces will be built.

In all the Swedish Bessemer works, as hitherto conducted, the pig-iron is taken directly from the blast-furnace without remelting. In the movable furnaces (converters) charges of 2,300 to 3,900 kilograms are employed. The converters have six to seven brick tuyeres, each of which has six to seven holes, with a diameter of 11 to 18 millimeters. The pressure of blast is usually between 600 and 900 millimeters of mercury, and the whole process is finished generally in 4 to 10 minutes. With the exception of Sandvicken, where steam is partly used, all the larger Bessemer works use water-power entirely. The blowing-engines, both at the above-named works and those lately erected, are from 350 to over 500 horse-power.

At some Bessemer works 1 or 2 per cent. of spiegel iron is added toward the close of the process; in others, however, which work more manganiferous ores, no addition of spiegel is necessary, since as soft an

iron as desired may be produced in them without danger of redshortness.

Of the weight of pig-iron used, 85 to 89 per cent. Bessemer ingots is generally obtained, and only a few per cent. of waste.

143. *Martin steel, cement-steel, &c.*—Since the year 1868, at Munkfors, cast steel has been produced in a Siemens regenerating-furnace with a Lundin condenser, according to the method of Martin. Also, at Lesjöfors, such steel has begun to be produced, and experiments on a smaller scale have been commenced at some other works.

The furnaces are small, holding only 800 to 1,300 kilograms. For fuel air-dried wood is used; 6 to 7.4 cubic meters per ton of melted steel or iron. The most noticeable fact is that in this way uniformly-soft iron can be produced successfully, which is rolled into nail-iron or wire.

At Wiksnanshyttan cast steel is produced by the Uchatius method, from granulated pig-iron mixed with powder of rich ore and a little charcoal. The fusing takes place in graphite crucibles in ordinary English furnaces heated with coke. The steel produced in this way is suitable for such purposes as require great compactness with considerable hardness, as for dies, hammers, &c.

Hitherto cement-steel has been pretty generally produced, which is drawn before it goes into the market under various names. At Surahammar and Motala puddled steel is also produced, and at Graningo some raw steel is made on the hearth. In addition, cast-steel works have been erected at Österby for melting in crucibles in a Siemens-Lundin furnace, using wood as fuel.

The iron and steel manufacture is not yet great enough to satisfy the demands of the country itself; it is hoped, however, that in a few years quite different relations in this respect will come about, for all the greater Bessemer works mentioned below are intended for the manufacture of rails and other railroad material, together with sheet-iron.

144. ROLLING-MILLS.—The foremost of the rolling-mills, hitherto in operation, for sheet-iron is Motala, and next Surahammar and Kloster are the greatest, although at the last mentioned only thin plate, like wire-plate, &c., is made. At Surahammar puddled iron is used exclusively for the manufacture of plate; at Motala the Bessemer iron from this and other iron-works is used. At Kloster the Lancashire iron was formerly employed, but they have in view now the plan of using the Bessemer iron from Långshyttan, which belongs to the same company.

Iron rails of the ordinary dimensions at present can be produced at only two works, namely, Motala and Smedjebacken. At the first-named works, during the year 1871 there were rolled out—

	Kilograms.
Bessemer-steel rails	1,190,200
Puddled-iron rails	76,400
Puddled-iron rails with heads of Bessemer steel	870,900
Total	2,137,500

At Smedjebacken, in the same year, 1,083,792 kilograms of rails were rolled, 119,084 kilograms of which were from the Bessemer steel from from Bäcka, and the rest from Lancashire iron.

Car-wheels of wrought iron are manufactured only at Surahammar, where tires of puddled steel are also made; Sandviken is the only place, however, where tires have been made in large quantity, and from Bessemer steel hitherto.

At Surahammar car-axles of puddled steel are made, and at a few machine-shops machine-axles from iron-waste are made; but the chief places for the production of large axles at present are Motala, where they can be obtained either of Bessemer or puddled steel as desired; and also Fagersta and Sandviken, which make them only of Bessemer steel.

Nails are manufactured at many works and in very different ways, but this manufacture is carried on to the greatest extent in the provinces of Blekinge and Ostgothland, where they are made mostly by cutting out of plate, and next in Wermland, where they are produced mainly by machines from wire. Besides this, many nails are manufactured by hand.

A part of the Bessemer metal of Westanfors is worked at Fagersta, which belongs to the same proprietor, to gun-barrels, saws, and springs; but Eskilstuna is the chief place for the manufacture of small articles of iron and steel, like locks, tools, knives, arms, &c.

Wire is drawn at many works, as Kolsva, Bofors, Degerfors, Gunnebo, Lesjöfors, and Munkfors; but Lesjöfors is the main place for wire-drawing, and part of the wire is employed on the spot for the manufacture of rope and nails.

145. *Table showing the amount of ore obtained and the manufacture of pig and wrought iron, steel and manufactured wares, in the years* 1860, 1865, 1870, *and* 1871, *as far as it has been announced by the Royal Commercial College.*

	1860.	1865.	1870.	1871.
	Kilogs.	*Kilogs.*	*Kilogs.*	*Kilogs.*
Mine-ores	395, 145, 000	496, 824, 000	617, 037, 000	647, 119, 000
Bog-ores	22, 228, 000	20, 312, 000	13, 756, 000	15, 769, 000
Total iron-ores	417, 373, 000	517, 136, 000	630, 793, 000	662, 888, 000
Pig	179, 912, 000	221, 389, 000	293, 278, 000	293, 118, 000
Cast-iron wares produced directly at the blast-furnace.	5, 237, 000	5, 350, 000	7, 218, 000	5, 800, 000
Total cast iron	185, 149, 000	226, 739, 000	300, 496, 000	298, 918, 000
Bar, band, nail, wire iron. &c	136, 932, 000	148, 512, 000	193, 908, 000	187, 792, 000
Bessemer metal		4, 425, 000	6, 637, 000	*8, 038, 000
Other steel		2, 988, 000	5, 550, 000	4, 013, 000
Plate	24, 239, 000	5, 986, 000	5, 735, 000	6, 564, 000
Nails		5, 957, 000	4, 787, 000	6, 138, 000
Implements and sundries		7, 852, 000	10, 304, 000	14, 362, 000

* This number does not correspond with that of the Commercial College, for the production of Westanfors, Svartnäs, and Bächa, for 1871, is not included in the latter.

Table showing the export and import of ore, pig, cast, and wrought iron, steel, and manufactured wares in the years 1860, 1865, 1870, *and* 1871.

	1860.		1865.		1870.		1871.	
	Export.	Import.	Export.	Import.	Export.	Import.	Export.	Import.
	Kilogs.	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*
Ore	2, 254, 000	...	7, 745, 000	...	13, 126, 000	...	11, 902, 000	...
Pigs	12, 725, 000	2, 085, 000	16, 018, 000	4, 877, 000	39, 940, 000	5, 147, 000	41, 085, 000	7, 233, 000
Pigs in scrap	...	...	326, 000	...	464, 000	...	255, 000	...
Cast iron	1, 054, 000	596, 000	287, 000	45, 000	692, 000	46, 000	626, 000	221, 000
Blooms	1, 821, 000	...	3, 936, 000	...	7, 907, 000	...	10, 423, 000	...
Bar-iron	97, 657, 000	276, 000	89, 553, 000	1, 171, 000	135, 131, 000	974, 000	143, 335, 000	1, 364, 000
Band, nail iron, &c	1, 303, 000	418, 000	2, 423, 000	528, 000	18, 373, 000	806, 000	17, 906, 000	1, 227, 000
Rails	...	398, 000	...	21, 643, 000	359, 000	4, 766, 000	1, 071, 000	10, 050, 000
Plate	632, 000	122, 000	680, 000	356, 000	670, 000	1, 419, 000	784, 000	1, 720, 000
Nails and small articles	1, 227, 000	63, 000	1, 401, 000	174, 000	898, 000	182, 000	1, 106, 000	377, 000
Scrap-iron	780, 000	1, 000	1, 455, 000	30, 000	4, 118, 000	248, 000	4, 803, 000	323, 000
Steel	7, 244, 000	93, 000	4, 697, 000	100, 000	3, 281, 000	172, 000	5, 349, 000	310, 000
Steel-work	...	5, 784	...	4, 551	...	196, 020	...	16, 161
Iron and steel wire	27, 049	28, 750	44, 061	197, 041	59, 032	65, 454	95, 990	60, 775
Tinned plate	...	196, 786	...	312, 043	...	526, 819	1, 276	693, 452
	Francs.	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*	*Francs.*
Implements, railroad materials, and machines	53, 466	3, 069, 049	91, 045	3, 989, 932	1, 177, 648	4, 156, 094	552, 679	5, 217, 658

Table showing the ore obtained and the iron manufactured, as well as the number of hands, in the different provinces during the year 1871, *as published by the Royal Commercial College.*

Province.	Ore obtained.		Hands employed in obtaining the ore.				Pig-iron.					
	Mine-ores.	Bog-ores.	Steady hands.	Occasional hands.	Women and children.	Total number of persons.	No. of blast-furnaces out of blast.	No. of blast-furnaces in blast.	Entire time of blast.	Pig-iron produced in the form of— Pigs.	Cast iron.	Total pig-iron.
	Kilogs.	*Kilogs.*							*Days.*	*Kilogs.*	*Kilogs.*	*Kilogs.*
Norrbotten	21, 265			3		3	6					
Westerbotten							1	3	$344\frac{1}{4}$	2, 384, 997	221, 879	2, 606, 876
West-Norrland	928, 855		6	4	1	11	1	4	$480\frac{3}{4}$	3, 315, 724	80, 637	3, 396, 361
Jemtland	15, 736		6			6	1	1	$33\frac{1}{2}$	65, 326		65, 326
Gefleborg	22, 444, 697		197	10		207	8	19	3, $102\frac{1}{2}$	31, 166, 920	241, 698	31, 408, 618
Upsala	33, 132, 273		409	19	15	443	9	2	$333\frac{1}{2}$	2, 988, 753	83, 274	3, 072, 027
Stockholm	29, 367, 688		271	75	45	391	2	3	$391\frac{3}{4}$	3, 581, 324	89, 185	3, 670, 509
Kopparberg	178, 046, 656		750	73	116	939	19	45	7, 876	67, 736, 680	489, 903	68, 226, 583
Westmanland	92, 225, 667		375	54		429	10	16	2, 810	23, 054, 790	340, 708	23, 395, 498
Örebro	135, 690, 051		1, 054	165	38	1, 257	16	54	11, $046\frac{1}{4}$	86, 249, 181	2, 065, 895	88, 315, 076
Skaraborg		127, 590						1	259	1, 680, 530	48, 697	1, 729, 227
Wermland	121, 252, 392		855		85	940	6	26	5, $442\frac{3}{4}$	45, 395, 076	699, 014	46, 094, 090
Elfsborg								1	$68\frac{1}{2}$	413, 987	7, 188	421, 175
Gothenburg u. Bohus												
Södermanland	19, 231, 386		172	11	11	194	2	6	1, $224\frac{1}{2}$	5, 744, 867	489, 010	6, 233, 877
Ostgothland	4, 450, 169		38			38		4	1, 030	8, 355, 614	87, 229	8, 442, 843
Calmar	382, 770	555, 527	4	10	1	15	5	6	$759\frac{1}{4}$	4, 110, 269	75, 491	4, 185, 760
Jönköping	9, 910, 128	8, 911, 864	51	40		91	2	12	1, $610\frac{1}{2}$	5, 097, 901	420, 324	5, 518, 225
Kronoberg	19, 266	6, 174, 463	3	12		15	4	4	658	1, 775, 032	360, 357	2, 135, 389
Halland												
Blekinge												
Christianstad												
Malmöhus												
Total	647, 118, 999	15, 769, 444	4, 191	476	312	4, 979	92	207	37, 471	293, 116, 971	5, 800, 489	298, 917, 460

Table showing the ore obtained and the iron manufactured, as well as the number of hands, in the different provinces, &c.—Continued.

Province.	Bar-iron.		Steel.			Manufactured wrought iron.				Hands employed in the iron-works.			
			Bessemer steel.		Other steel, mainly shear-steel								
	Number of hearths in operation.	Bar-iron produced.	Number of works.	Product.	Product.	Plate.	Nails.	Rails.	Implements and sundries.	In the blast-furnaces.	In bar-iron works.	In manufacturing and casting.	Total number of persons.
		Kilogs.		*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*	*Kilogs.*				
Norrbotten	5	236, 807	...	...	...	...	29, 686	...	35, 470	...	29	15	44
Westerbotten	12	2, 387, 166	...	...	...	...	24, 242	...	89, 526	58	70	37	165
West-Norrland	37	4, 825, 752	...	...	6, 082	...	110, 238	...	442, 057	65	177	176	418
Jemtland	2	42, 190	...	...	...	...	2, 297	...	7, 060	4	7	9	20
Gefleborg	114	24, 816, 808	1	4, 135, 192	503, 470	...	122, 019	...	1, 927, 715	384	643	370	1, 397
Upsala	31	6, 294, 057	1	184, 282	80, 297	...	...	...	107, 558	56	222	21	299
Stockholm	14	2, 877, 878	...	...	...	...	33, 471	...	15, 949	75	122	687	874
Kopparberg	100	22, 999, 586	3	*1, 254, 975	186, 196	911, 758	280, 060	1, 083, 792	358, 400	844	786	475	2, 105
Westmanland	78	24, 541, 894	1	*2, 424, 210	1, 540, 054	1, 189, 734	45, 677	...	407, 097	329	649	698	1, 676
Örebro	114	32, 818, 445	1	39, 595	578, 876	...	375, 370	...	1, 332, 848	923	1, 095	192	2, 210
Skaraborg	12	1, 590, 750	...	...	...	...	97, 181	...	163, 868	18	60	132	210
Wermland	141	34, 635, 496	...	...	684, 265	...	1, 004, 729	...	1, 170, 043	505	1, 118	357	1, 980
Elfsborg	18	3, 932, 834	...	...	489, 052	...	194, 872	...	189, 811	21	133	116	270
Gothenburg u. B. Lus	1	22, 626	...	...	...	...	17, 182	...	312, 383	...	...	504	504
Södermanland	13	2, 027, 490	...	...	...	340, 240	296, 009	...	90, 121	105	76	230	411
Ostgothland	69	10, 569, 258	...	...	115, 426	3, 633, 848	1, 172, 169	2, 137, 500	1, 024, 930	91	418	581	1, 090
Calmar	30	5, 504, 233	...	...	3, 530	...	505, 937	...	446, 395	104	249	229	582
Jönköping	22	2, 154, 357	...	...	...	...	146, 686	...	400, 165	178	149	122	449
Kronoberg	11	1, 022, 932	...	...	...	...	175, 649	...	159, 743	52	70	129	251
Halland	...	...	...	...	...	...	...	...	5, 104	...	...	2	2
Blekinge	3	4, 491, 083	...	...	...	488, 287	1, 504, 541	...	15, 353	...	...	215	215
Christianstad	...	...	...	...	...	...	...	...	367, 332	...	...	75	75
Malmöhus	...	...	...	...	...	...	...	...	988, 525	...	...	223	223
Total	827	187, 791, 642	7	*8, 038, 254	4, 187, 248	6, 563, 867	6, 138, 015	3, 221, 292	10, 057, 453	3, 812	6, 073	5, 595	15, 480

* These numbers do not correspond with those of the Commercial College, for the production of Westanfors, Svartnäs, and Bäcka is omitted in the latter.

146. *Locality of greatest production.*—It is evident from the foregoing table that the greatest production of ore is in the province of Kopparberg, and then follow Örebro, Wermland, and Westmanland.

The largest production of pig-iron is in Örebro. Among the provinces rich in ore, Westmanland has the smallest production of pig-iron, not only absolutely but relatively to its production of ore. This is owing to the fact that a considerable part of the ore obtained from its largest mine, Norberg, is taken to other provinces, as Gefleborg, Kopparberg, Ostgothland, Calmar, West-Norrland, and Westerbotten, while the inhabitants of Westmanland use a great part of their abundance of coal for hearth-firing the pig-iron obtained from the provinces Kopparberg and Örebro. Also, in the provinces of Wermland and Kopparberg, the manufacture of pig-iron is small in proportion to the amount of ore obtained, since, as has been mentioned, a part of the ore of these provinces is taken to the blast-furnaces in the provinces of Örebro and of Kopparberg, and many other furnaces. By far the greatest part of the ore obtained in the provinces of Upsala and Stockholm is taken to other provinces, as Norrland, and to Ostgothland and Calmar. The last-named provinces, which are poor in ore, fetch their ore both from the Norberg, in the province of Westmanland, which has been already mentioned, and also from the region of Nora, in the province Örebro, from Grängesberg, and many other places in the province of Kopparberg.

Although the manufacture of bar-iron is greatest in the province of Örebro, yet it does not correspond to the production of pig-iron; for a great part of the pig-iron is sold as such partly to other provinces, partly to foreign countries. The same holds good, though in a less degree, of the province of Kopparberg, whence pig-iron, for the purpose of conversion into wrought iron, is imported into the provinces of Ostgothland, Westmanland, West-Norrland, Calmar, &c. The production of bar-iron is greatest in the provinces of Wermland and Örebro, and next following them Gefleborg, Westmanland, and Kopparberg.

As has been shown above, considerable interchange of ore and pig-iron takes place between the different provinces. This is partially accounted for by the fact that many works, in consequence of lack of fuel and other circumstances, can be carried on more advantageously in other places than in the neighborhood of the mine; partly also because some mines lie so near the boundary of the province that the transportation of the ore from one province to another is a small matter. On the other hand, the transportation would be wholly unnecessary if many works had not been in the beginning located disadvantageously, and, therefore, many alterations for the better may be expected when those now building, and possibly also other means of communication, shall have been completed.

147. CHEMICAL COMPOSITION OF SWEDISH ORES.—The following tables contain the results of analyses of the principal iron-ores of Sweden; the locality, name of the chemist, and a reference to the original publication:

Analyses of Swedish iron-ores.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore.					
					Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
IN THE PROVINCE OF NORRBOTTEN.										
Tornea Lappmarken, parish Juckasjervi.										
Kurunavara	S.	Raw	1872	C. A. Wrang	*88. 4 per cent. $Fe^3 O^4$	*0. 28	....	1. 62	(0. 04)	....
Luosavara	G.	Raw	1861	L. Rinman	*98. 5 " "	†0. 016	....	0. 107	....	0. 67 p. c. $Ti\ O^2$
Luleå Lappmarken, parish Gellivara.										
Gellivara, Herzog von Upland	G.	Raw	1862	L. Rinman	92. 1 per cent. $Fe^3 O^4$	....	....	0. 742	....	....
Gellivara, Törefors und Gyljen	G.	Raw	1862	do	94. 0 " "	....	....	0. 020	....	....
Gellivara, Tingvalls Hügel	G.	Raw	1862	do	90. 7 " "	....	....	0. 512	....	....
Gellivara, Robsahm	G.	Raw	1862	do	87. 8 " "	....	....	0. 038	....	....
Gellivara, Wälkomman	G.	Raw	1862	do	88. 5 per cent. $\left\{ \begin{matrix} Fe^3 O^4 \\ Fe^2 O^3 \end{matrix} \right\}$	....	....	0. 394	....	....
Gellivara, Friederike's Schürfen	G.	Raw	1862	do	92. 3 per cent. $Fe^2 O^3$	Trace	....	0. 019	....	....
Routivara	G.	Raw	1862	do	74. 9 per cent. $Fe^3 O^4$	0. 5	....	0. 004	Trace	9. 20 p. c. $Ti^2 O^3$
Parish Unter-Luleå.										
Hindersö	G.	Raw	1872	O. Baer	65. 9 per cent. $Fe^3 O^4$	0. 14	....	(0. 008)	(0. 04)	....
IN THE PROVINCE OF WEST-NORRLAND.										
Parish Nätra.										
Ulfö	G.	Raw	1872	A. Tamm	$\left\{ \begin{matrix} 30. 2 \text{ per cent. } Fe\ O \\ 15. 3 \text{ per cent. } Fe^2 O^3 \end{matrix} \right\}$	0. 69	0. 03 per ct. Cu.	0. 03	0. 01	9. 51 p. c. $Ti\ O^2$
IN THE PROVINCE OF GEFLEBORG.										
Parish Voxna.										
Gymås, Konst-Grube	G.	Roasted	1859	D. A. Kruhs	*48. 3 per cent. $Fe^3 O^4$	†0. 31	....	0. 061	(0. 1)	....

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore.					
					Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
PROVINCE OF GEFLEBORG—Continued.										
Parish Thorsåker.										
Nyäng, Alte Öster-Grube	G.	Raw	1868	A. Burén	*68.0 per cent. Fe^3O^4	†0.45	......	(0.004)	(0.05)	......
Nyäng, Neue Öster-Grube	G.	Raw	1868	G. Svedelius	79.4 " "	0.11	......	......	......	......
Nyäng, Wester-Grube	G.	Raw	1868	....do	70.5 " "	0.05	......	......	......	......
Nyäng, Nore	G.	Raw	1868	....do	49.5 " "	Trace	......	0.015	......	......
Erik Ers	......	Raw	1863	L. Rinman	77.8 " "	3.60	......	0.008	0.3	......
Penning	G.	Raw	1860	G. L. Wetterdal	*60.3 " "	†14.6	......	0.0[illegible]2	(0.04)	......
Do	G.	Raw	1868	G. Svedelius	71.1 " "	11.62	......	0.008	0.02	......
Malmberg	G.	Raw	1868	....do	51.1 " "	Trace	......	0.008	0.009	......
Gösk, Erz No. 3	G.	Raw	1868	A. Tamm	28.7 " "	0.54	......	0.013	Trace	......
Nyberg	G.	Raw	1868	G. Svedelius	71.4 " "	Trace	......	0.022	0.053	......
Masmästaren	G.	Roasted	1872	J. E. Eklund	67.7 " "	1.02	......	......	......	......
Fogelmossen	G.	Raw	1872	J. E. Eklund	38.4 " "	2.98	......	......	......	......
Hedberg	G.	Raw	1868	G. Svedelius	79.6 " "	0.14	......	0.015	Trace	......
Afze	......	Raw	1862	H. Limnelius	26.0 " "	5.59	......	0.010	(0.06)	......
Afze, Erz No. 1	G.	Raw	1868	G. Svedelius	58.2 " "	3.14	......	0.008	0.94	......
IN THE PROVINCE OF UPSALA.										
Parishes Films and Dannemora.										
Dannemora, Harnäs Hauptgattirung, 1866.	G.	Roasted	1866	C. A. Löthner	*74.9 per cent. Fe^3O^4	†1.53	......	(0.008)	(0.04)	......
Dannemora, Nördl. Feld, (die bei Harnäs gebrauchten Erze von hier.)	G.	Roasted	1866	C. A. F. Reuterskiöld.	*74.7 " "	†1.52	......	(0.01)	(0.03)	......
Dannemora, Nördl. Feld, Nördl. Kungs-Grube.	G.	Raw	1865	B. Fernqvist	70.7 " "	2.00	......	0.0026	0.08	......
Dannemora, Zwischenfeld, De Geer, Jord-Grube.	G.	Raw	1865	....do	77.4 " "	1.60	......	0.0026	0.033	......

Dannemora, Südl. Feld, (die bei Harnäs gebrauchten Erze von hier.)	G.	Roasted	1866	O. Aspelin	*75. 5 " "	†2. 34	(0. 03 per ct. Cu.)	(0. 01)	(0. 03)	
Dannemora, Südl. Feld, Südlicher Silfberg.	G.	Raw	1865	B. Fernqvist	85. 8 " "	1. 50		0. 0033	0. 013	
Parish Alunda.										
Hammarin	G.	Roasted	1872	O. Alströmer	*73. 6 per cent. $Fe^3 O^4$	†1. 75		(0. 02)	(0. 08)	
Parish Lena.										
Sahlsta	G.	Raw	1863	L. Rinman	80. 2 per cent. $Fe^3 O^4$	0. 15		0. 015	0. 05	
Lenaberg, Zwischengrube	S.	Raw	1872	J. E. Eklund	*91. 9 " "	†0. 54		(0. 012)		
Brunna		Raw	1872	do	*81. 7 " "	†0. 20		(0. 0075)		
IN THE PROVINCE OF STOCKHOLM.										
Parish Wahlö.										
Vigelsbo, Stockenströms-Grube	G.	Raw	1870	J. W. Lewert	*68. 8 per cent. $Fe^3 O^4$	†0. 30		(0. 01)	(0. 04)	
Vigelsbo, Myr-Grube	G.	Raw	1870	E. S. Steffansson	*67. 1 " "	†0. 23			(0. 03)	
Parish Börstil.										
Sand	G.	Raw	1868	A. V. Blomberg	*74. 2 per cent. $Fe^3 O^4$	†0. 49		(0. 03)	(0. 02)	
Skedika, Nördliche	G.	Roasted	1866	T. Casselli	75. 9 " "	0. 36		0. 046	(0. 03)	
Parish Öregrund or Gräsö.										
Sladdarö	G.	Raw	1863	L. Rinman	79. 0 per cent. $Fe^3 O^4$	0. 25		0. 013	0. 045	
Parish Häfverö.										
Herräng, Lapp-Grube	G.	Raw	1867	G. Svedelius	73. 3 per cent. $Fe^3 O^4$	0. 37		0. 010	0. 021	
Parish Singö.										
Singö, Boudd-Grube	G.	Raw	1871	A. Tamm	*74. 0 per cent. $Fe^3 O^4$	†0. 14		(0. 005)	(0. 2)	
Parish Österhanninge.										
Utö	G.	Roasted	1862	J. A. Kullström	*53. 6 per cent. $Fe^2 O^3$	†0. 53	(0. 06 per ct. Cu.)	(0. 165)	(0. 04)	
IN THE PROVINCE OF KOPPARBERG.										
Parish Leksand.										
Sörskog, Erz No. 2		Raw	1859	C. Wahlund	*57. 2 per cent. $Fe^3 O^4$	†1. 23		0. 005	(0. 05)	
Parish Åhl.										
Sommarberg	G.	Roasted	1858	G. Hjort af Ornäs	*48. 7 per cent. $Fe^3 O^4$	†0. 93				
Blackberg	G.	Roasted	1858	F. Lindebäck	*58. 2 " "	†0. 35		(0. 042)		

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore. Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
PROVINCE OF KOPPARBERG—Continued.										
Parish Svärdsjö.										
Vinkärn, Svartnäs Mischung ……….	G.	Roaste .	1871	G. Réhn………..	{ 48. 2 per cent. $Fe^2 O^3$.. } { 15. 7 per cent. Fe O .. }	0. 15	………………	………	………	………………
Vinkärn, Gammel-Grube ……………	G.	Raw ….	1864	A. Andersson…..	*59. 5 per cent. $Fe^3 O^4$….	†0. 12	………………	(0. 03)	(0. 01)	………………
Vinkärn, Öster-Grube ………………	G.	Raw ….	1868	T. Annerstedt ….	*64. 0 " " ….	†0. 21	………………	………	………	………………
Parish Kopparberg.										
Harmsarf …………………………….	G.	Roasted.	1860	A. Carlsson ……	*72. 7 per cent. $Fe^3 O^4$…	†0. 27	………………	0. 026	………	………………
Parish Stora Tuna.										
Hästberg …………………………….	G.	Roasted.	1856	C. A. Jacobsson …	*69. 0 per cent. $Fe^3 O^4$….	†0. 4	………………	0. 02	(0. 04)	………………
Do…………………………………	G.	Roasted.	1872	C. A. Wrang ……	69. 0 " " ….	0. 04	………………	0. 024	………	………………
Romme, Örn-Grube………………….	G.	Roasted.	1866	J. Bratt………..	*77. 6 " " ….	†0. 48	(0. 07 per ct. Cu.)	(0. 017)	(0. 03)	………………
Parish Säter.										
Stora Bispberg, Prima Erz………….	G.	Roasted.	1871	J. Ekman……….	{ 68. 8 per cent. $Fe^2 O^3$.. } { 21. 7 per cent. Fe O .. }	0. 16	(0. 01)……….	0. 008	………	………………
Parish Husby.										
Rellingsberg………………………….	G.	Roasted.	1866	J. Wiborgh…….	*84. 2 per cent. $Fe^3 O^4$….	†0. 41	………………	(0. 008)	(0. 02)	………………
Rellingsberg, Prima Erz…………….	G.	Raw ….	1871	W. Lagergren…..	88. 7 " " ….	0. 45	………………	(0. 007)	(0. 03)	………………
Parish Garpenberg.										
Långvik …………………………….	G.	Roasted.	1861	J. F. Lundberg…	*60. 4 per cent. $Fe^3 O^4$….	†8. 01	Trace of Cu…..	(0. 02)	(0. 02)	………………
Holm…………………………………	G.	Roasted	1861	….do ………….	*64. 9 " " ….	†7. 25	{ 0. 005 p. c. Cu. } { 0. 13 p. c. Pb. }	(0. 02)	(0. 05)	………………

Parish By.										
Vestansjö, Secunda Erz	S.	Raw	1859	W. Tham	*55. 3 per cent. Fe^3O^4	†0. 30		Trace	(0. 04)	
Parish Folkärna.										
Knutsbo	G.	Roasted.	1861	J. F. Lundberg	*64. 0 per cent. Fe^2O^3	†1. 36		(0. 02)	(0. 03)	
Parish Grangärdes.										
Hästberg oder Fäboback	G.	Raw	1872	A. Tamm	{ 23. 7 per cent. Fe^2O^3 } { 15. 1 per cent. Fe O }	6. 79		(0. 06)	(0. 034)	
Grängesberg:										
Grängesbergsfeld, nördliches, Enkulle-Grube.	G.	Raw	1861	L. Rinman	82. 5 per cent. Fe^2O^3	Trace		0. 101	(0. 02)	
Grängesbergsfeld, südliches, Bredsjöbrottet.	G.	Raw	1861	do	89. 9 per cent. Fe^3O^4			0. 502	(0. 04)	
Grängesbergsfeld, südliches, Galthufvud-Grube.	G.	Raw	1861	do	85. 5 per cent. Fe^2O^3			0. 118	(0. 04)	
Ormbergsfeld, östl., Kittel-Grube	G.	Raw	1861	do	81. 9 " "			0. 129	(0. 03)	
Ormbergsfeld, östl., Björnhytte-u. Badstu Grube.			1865	C. H. Lundström	80. 6 " "	0. 52		0. 121	(0. 045)	
Do	G.	Raw	1872	A. Tamm	{ 68. 0 per cent. Fe^2O^3 } { 12. 9 per cent. Fe O }	Trace		(0. 119)	(0. 04)	
Ormbergsfeld, westliches, Tviste Granlund.			1865	C. H. Lundström	81. 0 per cent. Fe^2O^3	0. 11		0. 088	(0. 027)	
Ormbergsfeld, westliches, Abrahams-Grube.	G.	Raw	1861	L. Rinman	84. 1 per cent. Fe^3O^4			1. 27	(0. 02)	
Ormbergsfeld, westliches, Kleine Pick-Grube.	G.	Raw	1861	do	96. 5 per cent. Fe^2O^3			0. 065	(0. 03)	
Bäckberg, Bultar-Grube	G.	Raw	1864	O. H. Sillén	*60. 9 per cent. Fe^3O^4	†0. 15		(0. 12)	(0. 03)	
Parish Ludvika.										
Finnäs, Byberg-Grube	G.	Raw	1867	G. Svedelius	68. 9 per cent. Fe^3O^4	0. 51		0. 031	Trace	
Fredmundsberg, Compagnie-Grube	G.	Raw	1871	A. Tamm	{ 52. 7 per cent. Fe^2O^3 } { 26. 3 per cent. Fe O }	0. 10		1. 175	Trace	
Fredmundsberg, Tägt-Grube	S.	Raw	1863	J. F. Lundberg	*69. 3 per cent. Fe^3O^4	†0. 44		(0. 05)	(0. 04)	
Iviken, Lång-Grube	G.	Roasted.	1861	J. N. Björlingsson.	*64. 7 per cent. Fe^2O^3	†0. 87		(0. 09)	(0. 03)	
Iviken, Lejon-Grube	G.	Raw	1860	C. H. Lundström	73. 5 per cent. Fe^3O^4	0. 46		0. 034	0. 090	
Iviken, Femman-Grube	G.	Roasted.	1860	W. Tham	48. 8 " "	0. 15				
Iviken, Ko-Grube	G.	Raw	1867	G. Svedelius	77. 0 " "	Trace		0. 045	0. 007	
Do	G.	Raw	1872	A. Tamm	{ 53. 4 per cent. Fe^2O^3 } { 14. 5 per cent. Fe O }	0. 56		(0. 065)		
Gräsberg, Stor-Grube	G.	Raw	1867	G. Svedelius	65. 5 per cent. Fe^3O^4	0. 23		(0. 022)	0. 001	
Gräsberg, Herkules-Grube	G.	Raw	1867	do	74. 8 per cent. Fe^2O^3	0. 19		(0. 030)	0. 016	
Gräsberg, Kapitän-Grube	G.	Roasted	1859	C. W. Rinman	*61. 2 per cent. { Fe^2O^3 } { Fe^3O^4 }	†0. 30		(0. 043)	(0. 02)	
Gräsberg, Sultin-Grube	G.	Raw	1867	G. Svedelius	66. 5 per cent. Fe^2O^3	0. 63		(0. 033)	Trace	

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore. Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
PROVINCE OF KOPPARBERG—Continued.										
Parish Ludvika.										
Håksberg, nördlicher, Släd-Grube	G.	Raw	1871	A. Tamm	*70.0 per cent. Fe^2O^3 / Fe^3O^4	†0.01	....	(0.204)	(0.02)	....
Håksberg, nördlicher, Persbo	G.	Raw	1871	do	*70.4 per cent. Fe^3O^4	†0.03	....	(0.196)	(0.01)	....
Håksberg, südlicher, Spår-Grube	G.	Raw	1871	do	67.0 per cent. Fe^2O^3 / 11.3 per cent. $Fe\,O$	0.08	....	(0.063)	....	....
Parish Norrbärke.										
Östanberg, Smed Grube	G.	Raw	1861	L. Rinman	64.2 per cent. Fe^3O^4	....	....	0.0096	0.058	....
Nyberg, Risberg-Grube	G.	Roasted	1859	G. Hjort af Ornäs	*58.2 " "	†0.62	....	0.017	(0.01)	....
Svartberg, Svart-Grube	G.	....	1869	J. G. Wiborgh	60.8 " "	19.98	....	....	....	....
Svartberg	....	....	....	....	56.9 " "	18.42	....	0.010	1.34	....
Hilläng	G.	Raw	1872	A. Tamm	27.3 per cent. $Fe\,O$ / 22.6 per cent. Fe^2O^3	13.03	....	(0.021)	....	....
Torrstensberg, nördlicher, Tysk Grube	G.	Raw	1867	G. Svedelius	66.8 per cent. Fe^3O^4	0.33	....	0.017	Trace	....
Parish Sörbärke.										
Cedercreutz	S.	Raw	1865	T. Heijkenskjöld	*53.1 per cent. Fe^3O^4	†3.62	....	(0.014)	(0.03)	....
IN THE PROVINCE OF WESTMANLAND.										
Parish Norberg.										
Norberg:										
Risbergsfeld, Panzar	G.	Raw	1856	L. Rinman	70.2 per cent. Fe^2O^3	....	....	0.028	0.005	....
Risbergsfeld, Allmänning	G.	Raw	1872	E. Brusewitz	71.6 " "	0.15	....	0.032	....	....
Risbergsfeld, Spettal	G.	Raw	1864	B. Fernqvist	71.3 " "	0.15	....	0.003	0.006	....
Ragvaldsfeld, Förenings-Grube	....	....	1863	P. H. Fagerholm	*77.6 " "	†0.34	....	0.05	0.03	....
Smörbergsfeld, Hackspik-Grube	G.	Raw	1866	B. Fernqvist	64.0 per cent. Fe^3O^4	0.10	....	0.014	0.003	....
Rörbergsfeld, südliche Hag-Grube	S.	Raw	1872	E. Brusewitz	24.4 per cent. Fe^2O^3	34.59	....	0.044	....	....
Morbergsfeld, altes, grosse By-Grube	G.	Raw	1866	B. Fernqvist	69.0 " "	0.05	....	0.034	0.021	....

Morbergsfeld, altes, Flik	G.	Raw	1856	L. Rinman	68.5 " "			0.014	0.008	
Do	G.	Raw	1856	A. F. Groth	*68.2 " "	†0.25		0.016	(0.01)	
Morbergsfeld, altes, Örling	G.	Roasted	1861	J. F. Lundberg	*70.4 " "	†0.21		(0.03)	(0.05)	
Kallmorbergsfeld, Norr-Grube		Raw	1872	A. Tamm	{ 59.4 per cent. Fe^2O^3 } { 26.3 per cent. $Fe\ O$ }	0.17		0.003	(0.06)	
Kallmorbergsfeld, Svartberg	G.	Raw	1863	H. Klint	*64.3 per cent. Fe^3O^4	†0.55		(0.09)	(0.03)	
Kallmorbergsfeld, Torf-Grube, westl. Schacht.		Raw	1872	C. Böös	91.0 per cent. Fe^2O^3	0.32			(0.03)	
Bålsjöbergsfeld, grosse Badstu-Grube	S.	Raw		O. M. Kollberg	86.6 " "	0.04		0.018		
Bålsjöbergsfeld, kleine Badstu-Grube	G.	Raw	1866	B. Fernqvist	79.3 " "	0.05		0.021	0.009	
Bålsjöbergsfeld, Holm-Grube			1867	O. M. Kollberg	73.7 " "	0.20		0.022		
Klackbergsfeld, Näsberg	G.	Raw	1864	B. Fernqvist	41.7 per cent. Fe^3O^4	1.30		0.018	0.227	
Do	G.	Raw	1872	E. Brusewitz	69.5 " "	5.08		0.010		
Klackbergsfeld, Gröndal		Raw	1863	E. Dufva	*77.8 " "	†3.66		(0.01)	(0.02)	
Do	G.	Raw	1863	L. Rinman	73.6 " "	5.50		0.006	0.20	
Klackbergsfeld, Johannisberg	S.	Raw		O. M. Kollberg	84.9 " "	0.10		0.011		
Klackbergsfeld, Granrot	G.	Raw	1856	L. Rinman	70.0 " "	7.00		Trace.		
Do	G.	Raw	1864	do	76.0 " "	10.4		0.004	0.008	
Böjmossfeld, neue Kron-Grube	G.	Raw	1866	B. Fernqvist	72.2 per cent. Fe^2O^3	0.25		0.037	0.002	
Stripåsfeld, kleine Ny-Grube	G.	Raw	1864	P. Edman	*42.9 per cent. Fe^3O^4	Trace.		(0.02)	(0.03)	
Stripåsfeld, Redvägs-Grube	G.	Raw	1863	C. F. Tholander	*72.5 per cent. Fe^2O^3	†0.31		(0.06)	(0.03)	
Parish Westanfors.										
Flinthed	G.	Raw	1857	O. M. Kollberg	73.5 per cent. Fe^3O^4	3.56		0.007		
Stortägt, östliche, bei Semla	G.	Raw	1870	E. Brusewitz	66.9 " "	0.81		0.007		
Parish Skinnskatteberg.										
Bastnäs, Grosse Lång-Grube	G.	Roasted	1859	J. F. Lundberg	65.1 per cent. { Fe^2O^3 / Fe^3O^4 }	Trace.		0.009	(0.02)	
Parish Sala.										
Springan	G.	Roasted	1857	J. F. Lundberg	70.3 per cent. { Fe^2O^3 / Fe^3O^4 }	0.70		0.012	0.075	
Badstu-Grube in d. Nähe von Springan	G.	Roasted	1862	C. G. Lindegren	*54.2 " "	†0.47		(0.047)	(0.03)	
Ny-Grube in d. Nähe von Springan	G.	Roasted	1862	O. Biörck	*53.5 " "	†1.49	(0.03 per ct. Cu.)	(0.02)	(0.03)	
Lugndal	S.	Raw	1855	D. Engelbrecht	*57.8 " "	†2.53				
IN THE PROVINCE OF ÖREBRO.										
Parish Nya Kopparberg.										
Grängesberg:										
Lombergsfeld, Dam-Grube			1867	E. Carlsson	*76.2 per cent. Fe^2O^3	†0.11		(0.067)	(0.03)	
Lombergsfeld, Storbotten	G.	Raw	1863	C. H. Lundström	71.3 " "	0.10		0.076	0.04	
Lombergsfeld, Fall-Grube	G.	Raw	1863	do	78.2 " "	0.33		0.08	0.04	
Slättfall	G.	Raw	1865	B. Fernqvist	86.0 per cent. Fe^3O^4	0.14	0.003 per ct. Cu.	0.012	0.088	
Svartvik	G.	Raw	1863	C. H. Lundström	66.3 " "	2.68		0.01	0.05	
Svartvik, Qvarn-Grube	G.	Raw	1862	L. Rinman	73.6 " "	3.50		Trace.	0.043	
Ställberg, Kungs-Grube			1870	P. M. Carlberg	*64.8 " "	†4.16		(0.01)	(0.04)	
Källfall	G.	Raw	1865	B. Fernqvist	88.0 " "	0.07		0.007	0.008	

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore. Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
PROVINCE OF ÖREBRO—Continued.										
Parish Nya Kopparberg.										
Långblå, nördlich	G.	Raw	1865	B. Fernqvist	66.0 per cent. $Fe^3 O^4$	0.78	Trace of Cu	0.009	0.041	
Långblå, südliche	G.	Raw	1865	...do	67.3 per cent. $Fe^2 O^3$	0.09		0.004	0.023	
Stormossen	G.	Raw	1865	...do	65.8 per cent. $Fe^3 O^4$	0.36	Trace of Cu	0.011	0.013	
Elgkärns kulle	G.	Raw	1865	...do	63.7 " "	0.36		0.012	0.009	
Carls-Grube	G.	Raw	1865	...do	93.7 " "	0.19	Trace of Cu	0.003	0.004	
Smalkärn	G.	Raw	1863	C. H. Lundström	87.9 " "	0.60		0.012	0.04	
Parish Ramsberg.										
Strossa	G.	Raw	1862	L. Rinman	67.5 per cent. $Fe^3 O^4$	0.65		0.004	0.11	
Persberg	G.	Raw	1870	A. Olson	66.7 " "	2.06		0.022		
Parish Linde.										
Gränshyttan, Moss-Grube	G.	Raw	1862	L. Rinman	77.0 per cent. $Fe^3 O^4$	Trace		0.011	Trace	
Hammarbacken, Gladkärns-Grube	G.	Raw	1868	B. Fernqvist	28.7 per cent. $Fe^2 O^3$	25.8	Trace of As & Ni	0.051	0.076	
Stor-Grube, in d. Nähe v. Hammarbacken	G.	Roasted	1870	J. W. Lewert	*68.1 per cent. $Fe^3 O^4$	10.12				
Stripa	G.	Raw	1862	L. Rinman	{42.2 per cent. $Fe^2 O^3$ {40.7 per cent. $Fe^2 O^4$	Trace		0.005	Trace	
Linnäs, Hag-Grube	G.	Raw	1862	...do	42.7 " "	3.4		0.015	0.13	
Parish Hellefors.										
Björnhöjd	G.	Raw	1860	C. H. Lundström	69.1 per cent. $Fe^3 O^4$	0.60		0.20	0.06	
Björnhöjd, kleine oder neue	G.	Raw	1864	...do	84.9 " "	0.35		0.005	0.030	
Ställberg	G.	Raw	1864	...do	79.9 " "	0.15		0.023	0.05	
Åttman	S.	Raw	1867	B. Fernqvist	73.2 " "	1.47	Trace of Cu	0.003	1.818	
Ljungfall	S.	Raw	1867	...do	52.7 " "	1.82	...do	0.003	1.025	
Mörtkärn	S.	Raw	1867	...do	58.0 " "	0.49	...do	0.006	0.066	
Nymark	S.	Raw	1867	...do	63.8 " "	0.66		0.005	0.015	

Parish Grythytte.										
Högborn, Stoll-Grube	G.	Raw	1862	L. Rinman	80.3 per cent. $Fe^3 O^4$	0.10		Trace	0.01	
Parish Jernboas.										
Rastelf	G.	Raw	1872	B. Fernqvist	62.5 per cent. $Fe^3 O^4$	0.12		0.001	0.011	
Lakäng	G.	Raw	1866	do	79.0 " "	0.06		0.003	0.01	
Parish Nora.										
Striberg, Åsboberg	G.	Raw	1866	C. H. Lundström	86.7 per cent. $Fe^2 O^3$	0.05		0.019	0.05	
Striberg, Svartberg	G.	Raw	1866	do	79.7 per cent. $Fe^3 O^4$	0.45		0.007	0.045	
Striberg, Mossaberg	G.	Raw	1855	L. Rinman	71.5 per cent. $Fe^2 O^3$			0.052		
Striberg, Smedje-Grube	G.	Raw	1866	C. H. Lundström	71.4 " "	0.14		0.016	0.04	
Striberg, Stor-Grube	G.	Raw	1866	do	75.1 " "	0.19		0.023	0.05	
Striberg, Komminister-Grube	G.	Raw	1865	do	76.3 " "	0.07		0.013	0.06	
Striberg, obere Kärr-Grube	G.	Raw	1865	do	76.5 " "	0.14		0.020	0.055	
Lerberg, Djup-Grube	G.	Raw	1862	L. Rinman	83.9 per cent. $Fe^3 O^4$	0.15		0.002	Trace	
Pershyttan, Lock-Grube	G.	Raw	1866	B. Fernqvist	78.9 " "	0.16		0.018	0.007	
Do	G.	Raw	1866	do	75.5 per cent. $Fe^2 O^3$	0.03		0.02	0.025	
Pershyttan, Kittel-Grube	G.	Raw	1866	do	74.6 " "	0.15		0.025	Trace	
Pershyttan, nördliche Sjö-Grube	G.	Raw	1866	do	77.7 " "	0.05		0.022	0.006	
Wiker	G.	Roasted	1855	L. Rinman	66.4 per cent. $Fe^3 O^4$	4.90		0.027	0.044	
Do	G.	Roasted	1870	C. C'son Lindberg	66.1 " "	5.46		0.01	0.04	
Wiker, Erdmanns Schacht	G.	Raw	1866	C. H. Lundström	57.8 " "	5.38		0.034	0.269	
Do	G.	Raw	1870	J. F. Lundberg	57.3 " "	3.66		0.022	0.24	
Wiker, Ekertecklers Schacht	G.	Raw	1870	do	58.0 " "	3.84		(0.02)	0.23	
Dalkarlsberg, Flint-Grube, Erz No. 1	G.	Raw	1869	B. Fernqvist	87.4 per cent. $Fe^2 O^3$	0.09		0.029		
Dalkarlsberg, Flint-Grube, Erz No 2	G.	Raw	1869	do	77.7 " "	0.16		0.074		
Dalkarlsberg, Lång-Grube, Erz No. 1	G.	Raw	1869	do	81.2 " "	0.18		0.129	Trace	
Dalkarlsberg, Lång-Grube, Erz No. 2	G.	Raw	1869	do	69.3 " "	0.27	Trace of Cu	0.082	0.005	
Dalkarlsberg, Österrymning	G.	Raw	1859	C. L. Rinman	84.6 per cent. $Fe^3 O^4$	0.28		0.039	0.03	
Dalkarlsberg, Herr-Grube	G.	Raw	1859	do	88.6 " "	0.25		0.057		
Dalkarlsberg, Ny-Grube, Erz No. 2	G.	Raw	1868	C. H. Lundström	71.6 per cent. $Fe^2 O^3$	0.38		0.055	0.03	
Dalkarlsberg, Åkers-Grube, Erz No. 1	G.	Raw	1867	do	83.4 " "	0.33		0.031	0.015	
Dalkarlsberg, Orm-Grube, Erz No. 1	G.	Raw	1868	do	82.9 " "	0.14		0.052	0.035	
Dalkarlsberg, Fall-Grube	G.	Raw	1866	do	91.1 per cent. $Fe^3 O^4$	0.52		0.032	0.035	
Balkarlsberg, Fall-Grube, Erz No. 2	G.	Raw	1865	do	83.2 per cent. $Fe^2 O^3$	0.24		0.016	0.05	
Rödberg	G.	Raw	1864	B. Fernqvist	87.3 per cent. $Fe^3 O^4$	0.20	0.16 per ct. Cu	Trace	0.177	
Mo-Grube	G.	Raw	1864	do	94.4 " "	0.04	0.02 per ct. Cu	Trace	0.06	
Parish Winterasa.										
Sauna	G.	Raw	1865	B. Fernqvist	62.5 per cent. $Fe^3 O^4$	6.49	0.006 per ct. Cu 0.04 per ct. As	0.020	0.126	
Parish Knista.										
Nyberg, Prima Erz	G.	Raw	1871	F. O. Carlin	73.9 per cent. $Fe^3 O^4$	8.48		(0.01)	(0.07)	

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore.					
					Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
IN THE PROVINCE OF WERMLAND.										
Parish Gasborn.										
Fagerberg	G.	Raw	1862	C. H. Lundström	69. 1 per cent. $Fe^3 O^4$	2. 11	0. 12 per ct. Cu	0. 01	0. 33	
Do	S.	Raw	1867	B. Fernqvist	75. 2 " "	1. 83		0. 007	0. 131	
Do	G.	Roasted	1868	do	65. 9 per cent. $Fe^3 O^3$	1. 53	0. 08 per ct. Cu	0. 01	0. 013	
Hammar	G.	Raw	1863	C. H. Lundström	70. 2 per cent. $Fe^3 O^4$	0. 26		0. 01	0. 11	
Parish Nordmark.										
Taberg, nördlicher	G.	Raw	1863	L. Rinman	77. 8 per cent. $Ee^3 O^4$	0. 25		0. 013	0. 045	
Taberg, kleiner	G.	Raw	1863	do	73. 8 " "	0. 15		0. 013	0. 050	
Do	G.	Raw	1871	C. H. Lundström	70. 9 " "	0. 33	0. 056 per ct. Co. 0. 084 per ct. Zn. Trace of Cu	0. 014	0. 051	
Nordmark, Berg-Grube	G.	Raw	1863	L. Rinman	76. 3 " "	0. 50		0. 007	0. 027	
Nordmark, Ko-Grube	G.	Raw	1871	C. H. Lundström	74. 7 " "	0. 47	0. 044 per ct Zn. Trace of Cu Trace of Co	0. 009	0. 035	
Nordmark, Grundsjö und Brattfors	G.	Raw	1863	L. Rinman	82. 7 " "	0. 50		Trace	0. 012	
Finnmossen	G.	Raw	1871	C. H. Lundström	83. 8 " "	0. 43	0. 013 per ct. Co. 0. 014 per ct. Zn. Trace of Cu	0. 011	0. 045	
Parish Fernebo.										
Långban, Sicilien	G.	Raw	1863	L. Rinman	89. 4 per cent. $Fe^2 O^3$	Trace		0. 013	0. 024	
Persberg, Kran-Grube	G.	Raw	1850	L. F. Svanberg	69. 2 per cent. $Fe^3 O^4$	0. 044				
Persberg, Skärstöten	G.	Raw	1850	do	75. 1 " "	0. 02				
Persberg, Torskebäck	G.	Raw	1863	L. Rinman	76. 2 " "	0. 05		0. 002	0. 015	
Persberg, Gustav Adolph	G.	Raw	1864	C. H. Lundström	73. 4 " "	0. 20		0. 008	0. 03	
Persberg, Stor-Grube	G.	Raw	1850	L. F. Svanberg	73. 4 " "	0. 04				
Persberg, Jordåskärr	G.	Raw	1863	L. Rinman	82. 7 " "	0. 45		0. 001	0. 016	
Persberg, Jordås	G.	Raw	1865	C. H. Lundström	88. 2 " "	0. 18		0. 006	0. 06	

Persberg, Östra Hagen	G.	Raw	1863	L. Rinman	77.6 " "	Trace		0.013	0.20	
Persberg, Väg-Grube	G.	Raw	1865	C. H. Lundström	82.4 " "	0.24		0.005	0.027	
Persberg, Nord-Grube	G.	Raw	1863	L. Rinman	74.9 " "	0.25		0.024	0.045	
Persberg, Nord-Grube, nördliche	G.	Raw	1865	C. H. Lundström	72.8 " "	0.14		0.013	0.07	
Persberg, Dunderbacken	G.	Raw	1865	do	79.3 " "	0.18		0.011	0.06	
Högberg, Krakbo	G.	Raw	1863	L. Rinman	77.4 " "	0.15		0.012	0.01	
Limkärn	G.	Raw	1863	do	71.6 " "	0.40		0.007	0.04	
Do	G.	Raw	1863	C. H. Lundström	74.7 " "	0.68		0.011	0.06	
Limkärn, südliche oder Nyårs-Grube	G.	Raw	1863	do	77.1 " "	0.35		0.01	0.03	
Kyrkvik	G.	Raw	1867	do	68.3 " "	0.52		0.005	0.072	
Finshyttan, Eng-Grube	G.	Raw	1871	do	75.8 " "	0.57	0.012 per ct. Co; Trace of Zn	0.013	0.03	
Age, Fahlbäck	G.	Raw	1856	C. Ullgren	70.7 " "	0.97		0.028	0.207	
Age, Lejel	G.	Raw	1856	do	64.0 " "	1.16		0.025	0.179	
Mörkhult, Hallsat-Grube	G.	Raw	1856	F. L. Ekman	87.3 " "	0.59		Trace	0.02	
Mörkhult, Mörkhult-Grube	G.	Raw	1856	do	75.6 " "	0.39		Trace		
Gås-Grube, Blanka	G.	Raw	1868	C. H. Lundström	87.1 " "	0.37		0.016	0.10	
Nyttsta, Vret-Grube	G.	Raw	1866	do	80.5 " "	0.26		0.005	0.07	
Parish Kroppa.										
Dränke		Raw	1870	C. H. Lundström	72.5 per cent. $Fe^3 O^4$	0.210	0.054 per ct. Cu	0.030	0.055	
Tallholm	G.	Raw	1871	do	48.6 " "; 3.7 per cent. Fe O.	0.32		0.008	0.023	
IN THE PROVINCE OF SÖDERMANLAND.										
Parish Floda.										
Staf, alte	G.	Roasted	1859	L. A. v. Celsing	*53.3 per cent. $Fe^3 O^4$	†1.23		0.05		
Parish Sköldinge.										
Skalunda, Sophia		Raw	1860	L. E. Boman	79.5 per cent. $Fe^3 O^4$			0.06	(0.03)	
Wilhelmina		Raw	1859	C. Wahlund	80.2 " "	0.35		0.072	(0.03)	0.3 p. ct. TiO^2.
Parish Åker.										
Skotvång	G.	Roasted	1862	J. A. Kullström	*51.2 per cent. $Fe^3 O^4$	†0.30	(0.08 per ct. Cu.)	(0.032)	(0.02)	
Parish Gåsinge.										
Elgsjö	G.	Roasted	1862	J. O. Källgren	*68.8 per cent. $Fe^3 O^4$	†0.66		(0.04)	(0.03)	
Parish Svärtuna.										
Förola	G.	Roasted	1858	C. D. Tideström	*77.1 per cent. $Fe^3 O^4$	†0.48		0.01	(0.06)	
Do	G.	Raw	1870	C. H. Lundström	69.1 " "	0.24	0.12 per ct. Cu. and Co.	0.009	0.145	
Gillinge	G.	Raw	1870	do	63.3 " "	2.42	0.11 per ct. Co.	0.015	0.136	
Sjösa, Stor-Grube	G.	Raw	1866	O. Aspelin	*43.6 " "	†2.66		(0.068)	(0.03)	

Analyses of Swedish iron-ores—Continued.

Locality.	General or stufenprobe.	Roasted or raw.	When the assay or analysis was made.	Name of the one who made the analysis.	Occurring in the ore. Oxide of iron.	Protoxide of manganese.	Copper, cobalt, zinc, &c.	Phosphorus.	Sulphur.	Titanic acid or oxide.
PROVINCE OF SÖDERMANLAND—Continued.										
Parish Jerna.										
Jerna	G.	Roasted	1858	O. Troili	*86. 2 per cent. $Fe^3 O^4$	†0. 04	.....	0. 07	(0. 15)	.....
IN THE PROVINCE OF ÖSTERGÖTLAND.										
Parish Mogata.										
Petäng	G.	Raw	1858	J. A. M. Siberg	*61. 9 per cent. $Fe^3 O^4$	†0. 57	.....	(0. 01)	(0. 1)	.....
Parish Skällsvik.										
Nartorp, Prima Erz	G.	Raw	1860	A. F. Groth	*64. 4 per cent. $Fe^3 O^4$	†0. 17	.....	0. 016	(0. 07)	.....
Do	G.	Raw	1867	F. W. Degerman	*61. 1 " "	†0. 58	.....	(0. 04)	(0. 05)	.....
IN THE PROVINCE OF CALMAR.										
Parish Ukna.										
Stenebo	G.	Roasted	1858	M. Björkman	*75. 5 per cent. $Fe^3 O^4$	†0. 38	.....	(0. 03)	(0. 09)	.....
IN THE PROVINCE OF JÖNKÖPING.										
Parish Månsarp.										
Taberg	G.	Raw	1866	B. Fernqvist	43. 5 per cent. $Fe^3 O^4$	6. 40	0. 02 per ct. Cu.	0. 055	0. 013	6. 3 per ct. $Ti O^2$
IN THE PROVINCE OF KRONOBERG.										
Parish Ryssby.										
Långhult	G.	Raw	1865	....do	52. 9 per cent. $Fe^3 O^4$	0. 30	.....	0. 051	0. 019	8. 5 per ct. $Ti O^2$

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
IN THE PROVINCE OF NORRBOTTEN.														
Torneå Lappmarken, Parish Juckasjervi.														
Kurunavara	*64.0	25.8	1.1	63.2	6.5	3.4	......	13.7	......	0.5	......	0.8	20.6	Anal.-Buchd. Bergschule No. 2, 118.
Luosavara	*71.3	50.0	16.0	1.0	5.3	0.4	{ 17.2 per ct. Ti O^2 } { 10.1 per ct. $Ce^2 O^3$ }	26.7	6.7	7.5	2.1	0.1	2.4	{ Annalen des Eisen-Compt. 1861, p. 250.
Luleå Lappmarken, Parish Gellivara.														
Gellivara, Herzog von Upland	66.7	37.5	12.5	37.5	12.5	......	......	20.0	......	5.9	......	......	15.7	A. d. E. 1862, p. 363.
Gellivara, Törefors und Gyljen	68.1	55.2	14.6	7.8	22.4	......	......	29.4	......	6.9	......	......	8.6	Do.
Gellivara, Tingvalls Hügel	65.7	44.3	12.2	33.5	8.6	......	1.4 per ct. Be O	23.6	......	5.7	0.9	......	13.0	Do.
Gellivara, Robsahm	63.6	50.0	8.8	20.2	21.0	......	......	26.7	......	4.1	......	......	14.2	Do.
Gellivara, Wälkomman	63.9	62.7	2.7	28.0	6.6	......	......	33.4	......	1.3	......	......	10.6	Do.
Gellivara, Friederike's Schürfen	68.2	57.5	8.1	11.5	22.9	Trace.	......	30.7	......	3.8	......	Trace	12.4	Do.
Routivara	54.2	12.4	25.2	5.4	18.3	1.9	{ 35.5 per ct. $Ti^2 O^3$ } { 1.3 per ct. Be O }	6.7	11.5	11.7	0.8	0.4	8.8	A. d. E. 1862, p. 364.
Parish Unter-Luleå.														
Hindersö	47.7	45.1	15.2	11.1	28.2	0.4	......	24.0	......	7.1	......	0.1	14.4	A.-B. d. B. No. 2121.
IN THE PROVINCE OF WEST-NORRLAND.														
Parish Nätra.														
Ulfö	34.2	45.7	12.8	5.3	17.3	1.3	17.6 per ct. Ti O^2	34.4	6.9	6.0	......	0.3	8.4	A.-B. d. B. No. 1979.
IN THE PROVINCE OF GEFLEBORG.														
Parish Voxna.														
Gymås, Konst-Grube	*35.0	83.5	4.6	7.9	3.3	0.7	......	44.5	......	2.2	......	0.2	3.6	A. d. E. 1860, p. 476.

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
PROVINCE OF GEFLEBORG—Continued.														
Parish Thorsåker.														
Nyäng, Alte Öster-Grube	*49. 3	61. 2	5. 7	22. 5	9. 1	1. 5	......	32. 6	......	2. 7	......	0. 3	10. 1	A. d. E. 1869, p. 389.
Nyäng, Neue Öster-Grube	57. 0	53. 2	6. 7	25. 6	13. 9	0. 6	......	28. 3	......	3. 1	......	0. 1	12. 8	
Nyäng, Wester-Grube	50. 6	62. 8	2. 8	17. 8	16. 4	0. 2	......	33. 5	......	1. 3	......	0. 04	11. 6	
Nyäng, Nore	35. 5	62. 9	Trace	3. 9	33. 2	Trace	......	33. 5	......	......	......	......	14. 4	
Erik Ers	56. 4	32. 2	5. 2	29. 5	13. 3	19. 8	......	17. 2	......	2. 4	......	4. 5	13. 7	A. d. E. 1866, p. 142.
Penning	*43. 7	22. 9	3 6	15. 7	9. 3	48. 5	......	12. 2	......	1. 7	......	10. 9	8. 2	A. d. E. 1864, p. 389.
Do	51. 1	34. 6	5. 0	10. 1	9. 3	41. 0	......	18. 5	......	2. 3	......	9. 2	6. 6	
Malmberg	36. 9	49. 7	8. 0	23. 5	18. 8	Trace	......	26. 5	......	3. 7	......	......	14. 2	
Gösk, Erz No. 3	20. 8	32. 5	1. 7	61. 6	3. 2	1. 0	......	17. 3	......	0. 8	......	0. 2	18. 9	A. d. E. 1869, p. 381.
Nyberg	51. 3	78. 8	11. 9	1. 8	7 5	Trace	......	42. 0	......	5. 5	......	......	3. 5	
Masmästaren	49. 0	53. 8	Trace	12. 7	30. 4	3. 1	......	28. 7	......	......	......	0. 7	15. 8	
Fogelmossen	27. 8	10. 3	0. 2	63. 2	18. 8	7. 5	......	5. 5	......	0. 1	......	1. 7	25. 5	
Hedberg	55. 2	88. 0	2 8	0. 9	7. 7	0. 6	......	46. 9	......	1. 3	......	0. 1	3. 3	
Afze	18. 2	15. 7	8. 1	59. 0	6. 4	10. 8	......	8. 4	......	3. 8	......	2. 4	19. 4	A. d. E. 1864, p. 325.
Afze, Erz No. 1	41. 8	17. 6	4. 1	46. 2	22. 5	9. 6	......	9. 4	......	1. 9	......	2. 2	22. 2	
IN THE PROVINCE OF UPSALA.														
Parishes Films and Dannemora.														
Dannemora, Harnäs Hauptgattirung, 1866.	*54. 3	35. 4	3. 8	31. 1	23. 7	6. 0	......	18. 9	......	1. 8	......	1. 3	18. 4	A. d. E. 1869, p. 339.
Dannemora, Nördl. Feld, (die bei Harnäs gebrauchten Erze von hier.)	*54. 1	47. 1	9. 1	18. 2	20. 2	5. 4	......	25. 1	......	4. 3	......	1. 2	13. 3	A. d. E. 1869, p. 343.
Dannemora, Nördl. Feld, Nördl. Kungs-Grube.	51. 2	30. 3	3. 0	27. 4	30. 0	9. 3	......	16. 2	......	1. 4	......	2. 1	19. 8	A. d. E. 1866, p. 143.
Dannemora, Zwischenfeld, De Geer, Jord-Grube.	56. 1	33. 3	2. 9	23. 0	31. 6	9. 2	......	17. 8	......	1. 4	......	2. 1	19. 2	Do.

Dannemora, Südl. Feld, (die bei Harnäs gebrauchten Erze von hier.)	*54.7	44.3	5.5	18.8	19.7	11.7	......	23.6	......	2.6	......	2.6	13.2	A. d. E. 1869, p. 343.
Dannemora, Südl. Feld, Südlicher Silfberg.	62.2	35.2	6.5	23.6	21.7	13.0	......	18.8	......	3.0	......	2.9	15.4	A. d. E. 1866. p. 143.
Parish Alunda.														
Hammarin	*52.6	31.0	6.4	46.6	8.6	7.4	......	16.5	......	3.0	......	1.7	16.7	A.-B. d. B. No. 2132.
Parish Lena.														
Sahlsta	58.1	68.8	9.1	9.1	12.2	0.8	......	36.7	......	4.3	......	0.2	7.5	A. d. E. 1863, p. 243
Lenaberg, Zwischengrube	*66.6	45.1	16.4	4.8	22.7	11.0	......	24.0	......	7.6	......	2.5	10.4	
Brunna	*59.2	76.4	5.2	4.0	12.9	1.5	......	40.5	......	2.4	......	0.3	6.3	
IN THE PROVINCE OF STOCKHOLM.														
Parish Wahlö.														
Vigelsbo, Stockenströms-Grube	*49.9	48.2	14.0	10.0	26.3	1.5	......	25.7	......	6.6	......	0.3	13.4	A. B. d. B. No. 1826.
Vigelsbo, Myr-Grube	*47.2	54.1	10.3	16.0	18.7	0.9	......	28.9	......	4.7	......	0.2	9.9	A.-B.d.B. No. 1830.
Parish Börstil.														
Sand	*53.8	50.3	10.5	30.1	6.9	2.2	......	26.8	......	4.9	......	0.5	11.4	A. d. E. 1869, p. 390.
Skedika, Nördliche	55.0	45.8	18.9	9.2	24.5	1.6	......	24.4	......	8.8	......	0.4	12.4	A. d. E. 1869, p. 369.
Parish Öregrund or Gräsö.														
Sladdarö	57.2	67.3	7.6	12.3	11.6	1.2	......	35.9	......	3.6	......	0.3	8.2	A. d. E. 1863, p. 243.
Parish Häfverö.														
Herräng, Lapp-Grube	53.1	36.7	3.9	39.1	18.8	1.5	......	19.6	......	1.8	......	0.3	16.5	A. d. E. 1867, p. 252.
Parish Singö.														
Singö, Boudd-Grube	*53.6	41.2	19.1	14.4	24.6	0.7	......	22.0	......	8.9	......	0.2	13.9	A.-B. d. B. No. 1906.
Parish Österhanninge.														
Utö	*37.5	87.1	4.2	4.0	3.3	1.4	......	46.5	......	2.0	......	0.3	2.5	A. d. E. 1864, p. 335.
IN THE PROVINCE OF KOPPARBERG.														
Parish Leksand.														
Sörskog. Erz No. 2	*41.5	63.4	5.1	23.1	5.4	3.0	......	33.8	......	2.4	......	0.7	8.8	A. d. E. 1860, p. 429.
Parish Åhl.														
Sommarberg	*35.3	64.2	10.7	17.5	5.7	1.9	......	34.2	......	5.0	......	0.4	7.3	A. d. E. 1860, p. 469.
Blackberg	*42.2	59.3	4.5	30.3	4.9	1.0	......	31.6	......	2.1	......	0.2	10.6	A. d. E. 1860, p. 502.

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
PROVINCE OF KOPPARBERG—Continued.														
Parish Svärdsjö.														
Vinkärn, Svartnäs Mischung	46.0	55.5	6.2	30.2	7.7	0.4	......	29.6	......	2.9	......	0.1	11.7	A.-B. d. B. No. 2127.
Vinkärn, Gammel-Grube	*43.1	56.0	9.9	15.0	18.7	0.4	......	29.9	......	4.6	......	0.1	11.8	A. d. E. 1864, p. 421.
Vinkärn, Öster-Grube	*46.4	53.3	8.1	23.0	12.7	2.9	......	28.4	......	3.8	......	0.7	11.6	A. d. E. 1869, p. 384.
Parish Kopparberg.														
Harmsarf	*52.7	58.3	8.8	23.8	8.1	1.0	......	31.1	......	4.1	......	0.2	10.1	A. d. E. 1860, p. 486.
Parish Stora Tuna.														
Hästberg	*50.0	65.0	7.8	23.8	2.2	1.2	......	34.7	......	3.7	......	0.3	7.7	A. d. E. 1859, p. 359.
Hästberg	50.0	50.1	9.8	28.9	9.4	1.8	......	26.7	......	4.6	......	0.4	12.0	A.-B. d. B. No. 2130.
Romme, Örn-Grube	*56.2	47.2	9.4	12.9	28.0	2.5	......	24.5	......	4.4	......	0.6	14.8	A. d. E. 1869, p. 345.
Parish Säter.														
Stora Bispberg, Prima Erz	65.0	76.5	2.1	19.7	Trace.	1.7	......	40.8	......	1.0	......	0.4	5.6	A.-B. d. B. No. 2123.
Parish Husby.														
Rellingsberg	*61.0	49.3	9.7	23.4	15.0	2.6	......	26.3	......	4.5	......	0.6	12.7	A. d. E. 1869, p. 343.
Rellingsberg, Prima Erz	64.2	50.4	10.5	17.9	17.2	4.0	......	26.9	......	4.9	......	0.9	12.0	A.-B. d. B. No. 2143.
Parish Garpenberg.														
Långvik	*43.2	18.4	2.4	40.6	16.5	22.1	......	9.8	......	1.1	......	5.0	18.2	A. d. E. 1864, p. 303.
Holm	*47.0	37.1	1.9	22.6	15.4	23.0	......	19.8	......	0.9	......	5.2	12.6	A. d. E. 1864, p. 304.
Parish By.														
Vestansjö, Secunda Erz	*40.1	55.7	2.3	30.2	11.0	0.8	......	29.7	......	1.1	......	0.2	13.0	A. d. E. 1860, p. 431.

Parish Folkärna.														
Knutsbo	*44.8	76.6	2.4	7.9	9.3	3.8		40.9		1.1		0.9	6.0	A. d. E. 1864, p. 303.
Parish Grangärdes.														
Hästberg oder Fäboback	28.3	29.3	1.3	49.7	4.4	15.3		15.6		0.6		3.4	15.9	
Grängesberg:														
Grängesbergsfeld, nördliches, Enkulle-Grube.	57.8	77.8	11.7	3.2	7.3	Trace.		41.5		5.4			3.8	A. d. E. 1861, p. 250.
Grängesbergsfeld, südliches, Bredsjöbrottet.	65.1	39.2	22.1	14.1	24.6			20.9		10.3			13.8	Do.
Grängesbergsfeld, südliches, Galthufvud-Grube.	59.9	80.7	10.3	4.2	4.8			43.0		4.8			3.1	Do.
Ormbergsfeld, östl., Kittel-Grube	57.3	60.8	22.9	3.3	3.9		9.1 per cent. Ce^2O^3	32.4		10.7	1.9		2.5	Do.
Ormbergsfeld, ostl., Björnbytte-u. Badstu-Grube.	56.4	81.1	9.5	3.5	3.2	2.7		43.2		4.4		0.6	2.3	A. d. E. 1866, p. 287.
Do.	57.6	72.9	15.5	7.7	3.9	Trace.		38.9		7.2			3.7	
Ormbergsfeld, westliches, Tviste Granlund.	56.7	84.4	2.9	6.5	5.6	0.6		45.0		1.3		0.1	4.1	A. d. E. 1866, p. 287.
Ormbergsfeld, westliches, Abrahams-Grube.	60.9	62.1	9.4	20.5	8.0			33.1		4.4			9.0	A. d. E. 1861, p. 250.
Ormbergsfeld, westliches, Kleine Pick-Grube.	67.6	59.4	19.8	7.9	5.0		7.9 per cent. Ce^2O^3	31.7		9.2	1.6		4.2	Do.
Bäckberg, Bultar-Grube	*44.1	56.1	11.0	14.7	17.1	1.1		29.9		5.1		0.2	11.0	A. d. E. 1864, p. 405.
Parish Ludvika.														
Finnäs, Byberg-Grube	49.9	82.3	5.9	2.2	8.0	1.6		43.9		2.7		0.4	3.8	A. d. E. 1867, p. 251.
Fredmundsberg, Compagnie-Grube	57.3	58.6	6.0	25.1	9.7	0.6		31.2		2.8		0.1	11.0	A.-B. d. B. No. 1904.
Fredmundsberg, Tägt-Grube	*50.2	47.8	23.4	8.2	18.7	1.9		25.5		10.9		0.4	9.8	A. d. E. 1864, p. 341.
Iviken, Lång-Grube	*45.3	77.2	10.0	8.9	1.5	2.4		41.2		4.7		0.5	3.1	A. d. E. 1864, p. 324.
Iviken, Lejon-Grube	53.2	73.5	8.8	4.3	11.7	1.7		39.2		4.1		0.4	5.9	A. d. E. 1861, p. 338.
Iviken, Fenman-Grube	35.3	72.0	3.9	6.8	17.0	0.3		38.4		1.8		0.1	8.7	A. d. E. 1860, p. 496.
Iviken, Ko-Grube	55.7	87.7	6.9	3.3	2.1	Trace.		46.8		3.2			1.8	A. d. E. 1867, p. 252.
Do.	48.6	83.5	1.8	11.9	1.1	1.7		44.5		0.8		0.4	3.8	
Gräsberg, Stor-Grube	47.4	61.0	13.3	24.0	0.9	0.8		32.5		6.2		0.2	7.2	A. d. E. 1867, p. 251.
Gräsberg, Herkules-Grube	52.4	78.3	Trace.	12.9	8.1	0.7		41.8				0.2	6.9	Do.
Gräsberg, Kapitän-Grube	*43.7	83.1	6.1	2.7	7.3	0.8		44.3		2.8		0.2	3.7	A. d. E. 1860, p. 473.
Gräsberg, Sultin-Grube	46.6	85.1	2.9	5.1	5.1	1.8		45.4		1.3		0.4	3.5	A. d. E. 1867, p. 251.
Håksberg, nördlicher, Släd-Grube	*50.1	88.2	5.3	3.5	2.7	0.3		47.0		2.5		0.1	2.1	A.-B. d. B. No. 1901.
Håksberg, nördlicher, Persbo	*50.3	86.9	4.9	4.5	3.6	0.1		46.3		2.3		0.02	2.7	A.-B. d. B. No. 1902.
Håksberg, südlicher, Spår-Grube	55.7	85.1	6.7	4.0	3.8	0.4		45.4		3.1		0.1	2.6	A.-B. d. B. No. 1903.
Parish Norrbärke.														
Östanberg, Smed-Grube	46.5	71.0	7.4	14.2	7.4			37.9		3.4			7.0	A. d. E. 1861, p. 250.
Nyberg, Risberg-Grube	*42.2	61.8	2.4	20.8	14.4	1.6		33.0		1.1		0.4	11.7	A. d. E. 1860, p. 475.
Svartberg, Svart-Grube	43.9	26.3	2.7	8.9	7.8	54.3		14.0		1.3		12.2	5.6	
Do.	41.2	26.7	8.8	6.7	4.7	53.1		14.2		4.1		11.9	3.8	

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
PROVINCE OF KOPPARBERG—Continued.														
Parish Norrbärke.														
Hilläng	37.1	39.7	4.6	19.9	5.7	30.1	......	21.2	......	2.1	......	6.8	7.9	
Torstensberg, nördlicher, Tysk-Grube	48.4	82.4	12.4	Trace.	4.2	1.0	......	43.9	......	5.8	......	0.2	1.7	A. d. E. 1867, p. 251.
Parish Sörbärke.														
Cedercreutz	*38.5	63.3	4.8	12.6	10.2	9.1	......	33.8	......	2.2	......	2.0	7.7	A. d. E. 1869, p. 318.
IN THE PROVINCE OF WESTMANLAND.														
Parish Norberg.														
Norberg:														
Risbergsfeld, Panzar	49.1	75.9	1.0	19.4	3.7	......	......	40.5	......	0.5	......	......	7.0	A. d. E. 1861, p. 121.
Risbergsfeld, Allmänning	50.1	79.3	7.3	7.5	5.4	0.5	......	42.3	......	3.4	......	0.1	4.3	
Risbergsfeld, Spettal	49.9	89.5	1.7	7.9	0.4	0.5	......	47.7	......	0.8	......	0.1	2.4	A. d. E. 1866, p. 144.
Ragvaldsfeld, Förenings-Grube	*54.3	92.3	2.8	1.5	1.8	1.6	......	49.2	......	1.3	......	0.4	1.1	A. d. E. 1864, p. 387.
Smörbergsfeld, Hackspik-Grube	46.3	60.0	1.4	17.2	21.1	0.3	......	32.0	......	0.6	......	0.1	13.3	A. d. E. 1866, p. 246.
Rörbergsfeld, südliche, Hag-Grube	17.1	44.9	7.2	2.1	Trace.	45.8	......	23.9	......	3.4	......	10.3	0.6	
Morbergsfeld, altes, grosse By-Grube	48.4	91.5	1.9	5.4	1.0	0.2	......	48.8	......	0.9	......	0.04	1.9	A. d. E. 1866, p. 246.
Morbergsfeld, altes, Flik	48.0	83.2	1.9	9.6	5.3	......	......	44.4	......	0.9	......	......	4.8	A. d. E. 1861, p. 121.
Do	*47.8	47.9	Trace.	7.2	4.1	0.8	......	46.9	......	......	......	0.2	3.7	A. d. E. 1860, p. 468.
Morbergsfeld, altes, Örling	*49.3	81.0	3.2	9.9	5.2	0.7	......	43.2	......	1.5	......	0.2	4.9	A. d. E. 1864, p. 302.
Kallmorbergsfeld, Norr-Grube	62.1	59.2	Trace.	21.0	18.7	1.1	......	31.6	......	......	......	0.2	13.4	A.-B. d. B. No. 2019.
Kallmorbergsfeld, Svartberg	*46.6	89.4	4.5	2.7	2.4	1.0	......	47.7	......	2.1	......	0.2	1.7	A. d. E. 1864, p. 386.
Kallmorbergsfeld, Torf-Grube, westl. Schacht	63.7	83.5	3.5	7.8	1.5	3.7	......	44.5	......	1.6	......	0.8	2.8	A.-B. d. B. No. 2116.
Bålsjöbergsfeld, grosse Badstu-Grube	60.6	76.0	6.5	14.0	3.2	0.3	......	40.5	......	3.0	......	0.07	5.3	
Bålsjöbergsfeld, kleine Badstu-Grube	55.5	91.8	4.9	2.4	0.7	0.2	......	49.0	......	2.3	......	0.04	1.0	A. d. E. 1866, p. 246.
Bålsjöbergsfeld, Holm-Grube	51.6	82.2	10.6	5.2	1.2	0.8	......	43.8	......	5.0	......	0.2	2.0	
Klackbergsfeld, Näsberg	30.1	23.6	1.0	60.1	11.9	3.4	......	12.6	......	0.5	......	0.8	21.9	A. d. E. 1866, p. 141.

Klackbergsfeld, Näsberg	50.3	17.5	4.1	33.6	18.1	26.7	......	9.3	......	1.9	......	6.0	15.9	
Klackbergsfeld, Gröndal	*56.4	35.1	6.7	17.6	13.7	26.9	......	18.7	......	3.1	......	6.1	10.5	A. d. E. 1864, p. 333.
Do.	53.3	32.6	5.9	13.6	19.7	28.2	......	17.4	......	2.8	......	6.3	11.8	
Klackbergsfeld, Johannisberg	61.5	62.1	5.8	17.3	14.2	0.6	......	33.1	......	2.7	......	0.1	10.6	
Klackbergsfeld, Granrot	50.7	21.6	......	21.0	18.8	38.6	......	11.5	......	......	......	8.7	13.5	A. d. E. 1861, p. 121.
Do.	55.0	17.4	11.5	6.7	5.9	58.5	......	9.3	......	5.4	......	13.2	6.1	
Böjmossfeld, neue Kron-Grube	50.6	86.7	3.3	6.8	2.4	0.8	......	46.2	......	1.5	......	0.2	2.9	A. d. E. 1866, p. 247.
Stripåsfeld, kleine Ny-Grube	*31.1	56.5	8.5	22.5	12.5	Trace.	......	30.1	......	4.0	......	......	11.4	A. d. E. 1864, p. 396.
Stripåsfeld, Redvägs-Grube	*50.7	91.3	6.1	1.5	Trace.	1.1	......	48.7	......	2.8	......	0.2	0.4	A. d. E. 1864, p. 385.
Parish Westanfors.														
Flinthed	53.2	53.0	2.7	9.7	21.4	13.2	......	28.3	......	1.3	......	3.0	11.3	
Stortägt, ötsliche, bei Semla	48.4	82.0	3.9	6.4	5.3	2.4	......	43.7	......	1.8	......	0.5	3.9	
Parish Skinnskatteberg.														
Bastnäs, grosse Lång-Grube	46.0	87.1	4.1	4.3	4.5	Trace.	......	46.4	......	1.9	......	......	3.0	A. d. E. 1860, p. 455.
Parish Sala.														
Springan	50.2	60.2	12.0	20.6	4.7	2.5	......	32.1	......	5.6	......	0.6	7.7	A. d. E. 1860, p. 387.
Badstu-Grube in d. Nähe von Springan	*38.7	77.0	5.2	11.7	5.0	1.1	......	41.1	......	2.4	......	0.2	7.3	A. d. E. 1864, p 328.
Ny-Grube in d. Nähe von Springan	*38.2	57.1	8.9	26.9	3.6	3.5	......	30.4	......	4.1	......	0.8	9.1	A. d. E. 1864, p. 327.
Lugndal	*41.0	17.2	7.7	65.1	0.2	9.8	......	9.2	......	3.6	......	2.2	18.7	A. d. E. 1859, p. 334.
IN THE PROVINCE OF ÖREBRO.														
Parish Nya Kopparberg.														
Grängesberg:														
Lombergsfeld, Dam-Grube	*53.3	81.7	12.3	1.9	3.6	0.5	......	43.6	......	5.7	......	0.1	2.0	A. d. E. 1869, p. 357.
Lombergsfeld, Storbotten	49.9	85.3	8.4	3.9	2.0	0.4	......	45.5	......	3.9	......	0.1	1.9	A. d. E. 1864, p. 209.
Lombergsfeld, Fall-Grube	54.7	82.8	10.0	3.8	1.9	1.5	......	44.2	......	4.7	......	0.3	7.3	Do.
Slättfall	62.3	72.3	8.9	10.3	[illegible].5	1.0	......	38.6	......	4.1	......	0.2	5.9	
Svartvik	48.0	36.3	7.8	28.9	17.0	10.0	......	19.4	......	3.6	......	2.3	15.0	A. d. E. 1864, p. 209.
Svartvik, Qvarn-Grube	58.2	39.1	4.6	19.4	19.7	17.2	......	20.9	......	2.1	......	3.9	13.4	A. d. E. 1862, p. 365.
Ställberg, Kungs-Grube	*46.9	34.0	1.9	32.1	14.1	17.9	......	18.1	......	0.9	......	4.0	14.8	A.-B. d. B. No. 1837.
Källfall	63.8	55.5	6.4	18.1	19.4	0.6	......	29.6	......	3.0	......	0.1	12.9	
Långblå, nördliche	47.8	69.2	4.3	19.5	4.7	2.3	......	36.9	......	2.0	......	0.5	7.4	
Långblå, südliche	47.1	97.2	0.9	1.0	0.6	0.3	......	51.8	......	0.4	......	0.1	0.5	
Stormossen	47.7	77.7	3.5	14.4	3.3	1.1	......	41.4	......	1.6	......	0.2	5.4	
Elgkärns kulle	46.2	68.0	5.2	20.2	5.6	1.0	......	36.3	......	2.4	......	0.2	8.0	
Carls-Grube	67.9	62.8	8.0	15.9	10.3	3.0	......	33.5	......	3.7	......	0.7	8.6	
Smalkärn	63.6	60.4	12.0	17.8	5.0	4.8	......	32.2	......	5.6	......	1.1	7.1	A. d. E. 1864, p. 209.
Parish Ramsberg.														
Strossa	48.8	85.9	7.1	1.8	3.2	2.0	......	45.8	......	3.3	......	0.5	1.8	A. d. E. 1862, p 365.
Persberg	48.3	30.6	16.9	4.9	41.1	6.5	......	16.3	......	7.5	......	1.5	17.8	A.-B. d. B. No. 1840.
Parish Linde.														
Gränshyttan, Moss-Grube	55.7	90.8	4.0	3.0	2.2	Trace	......	48.4	......	1.9	......	......	1.7	A. d. E. 1862, p. 365.
Hammarbacken, Gladkärns-Grube	20.1	47.9	0.6	12.8	2.7	36.0	......	25.5	......	0.3	......	8.1	4.7	

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
PROVINCE OF ÖREBRO—Continued.														
Parish Linde.														
Stor-Grube in d. Nähe v. Hammarbacken	*49.3	81.5	8.8	4.4	4.9	0.4	....	43.5	......	4.1	......	0.1	3.2	A.-B. d. B. No. 1854.
Stripa	59.0	78.9	2.8	8.9	9.4	Trace	....	42.1	......	1.3	......	......	6.3	A. d. E. 1862, p. 365.
Linnäs, Hag-Grube	30.9	13.3	5.5	37.8	33.4	10.0	....	7.1	......	2.6	......	2.3	12.2	Do.
Parish Hellefors.														
Björnhöjd	50.0	50.9	11.5	23.4	12.3	1.9	....	27.1	......	5.4	......	0.4	11.6	A. d. E. 1861, p. 338.
Björnhöjd, kleine oder neue	61.5	65.3	6.1	13.5	12.8	2.3	....	34.8	......	2.8	......	0.5	8.8	A. d. E. 1865, p. 236.
Ställberg	57.8	55.7	15.9	7.7	19.9	0.8	....	29.7	......	7.4	......	0.2	10.1	Do.
Åttman	53.0	38.0	7.3	7.3	41.2	6.2	....	20.3	......	3.4	......	1.4	18.5	
Ljungfall	38.1	43.5	4.1	6.5	41.7	4.2	....	23.2	......	1.9	......	0.9	18.5	
Mörtkärn	42.0	46.9	2.8	5.1	44.0	1.2	....	25.0	......	1.3	......	0.3	19.0	
Nymark	44.2	49.1	3.0	5.3	40.7	1.9	....	26.2	......	1.4	......	0.4	17.8	
Parish Grythytte.														
Högborn, Stoll-Grube	58.1	50.4	9.1	21.7	18.3	0.5	....	26.9	......	4.2	......	0.1	13.5	A. d. E. 1862, p. 365.
Parish Jernboas.														
Rastelf	45.3	58.0	4.3	24.9	12.5	0.3	....	30.9	......	2.0	......	0.1	12.1	
Lakäng	57.2	60.6	8.0	6.8	24.3	0.3	....	32.3	......	3.7	......	0.1	11.6	
Parish Nora.														
Striberg, Åsboberg	60.7	60.6	19.4	10.5	9.1	0.4	....	32.3	......	9.0	......	0.1	6.6	A. d. E. 1866, p. 287.
Striberg, Svartberg	57.7	73.5	5.6	8.0	10.7	2.2	....	39.2	......	2.6	......	0.5	6.5	A. d. E. 1867, p. 150.
Striberg, Mossaberg	50.0	85.9	10.2	Trace.	3.9	......	....	45.8	......	4.8	......	......	1.5	A. d. E. 1861, p. 119.
Striberg, Smedje-Grube	49.9	91.4	1.4	5.6	1.1	0.5	....	48.7	......	0.6	......	0.1	2.0	A. d. E. 1867, p. 150.
Striberg, Stor-Grube	52.6	94.0	2.8	1.2	1.2	0.8	....	50.1	......	1.3	......	0.2	0.8	Do.

Striberg, Komminister-Grube	53.5	91.7	1.2	5.8	1.0	0.3	...	48.9	...	0.6	...	0.1	2.0	A. d. E. 1866, p. 287.
Striberg, obere Kärr-Grube	53.6	91.4	1.9	5.1	1.0	0.6	...	48.7	...	0.9	...	0.1	1.8	Do.
Lerberg, Djup-Grube	60.7	75.0	8.7	5.3	10.0	1.0	...	40.0	...	4.0	...	0.2	5.5	A. d. E. 1862, p. 365.
Pershyttan, Lock-Grube	57.1	85.3	9.9	2.2	1.9	0.7	...	45.5	...	4.6	...	0.2	1.4	
Do	52.9	84.4	10.0	3.3	2.2	0.1	...	45.0	...	4.7	...	0.02	1.8	
Pershyttan, Kittel-Grube	52.2	82.4	12.8	1.8	2.4	0.6	...	43.9	...	6.0	...	0.1	1.4	
Pershyttan, nördliche Sjö-Grube	54.4	85.9	8.8	2.4	2.7	0.2	...	45.8	...	4.1	...	0.04	1.7	
Wiker	48.1	44.3	13.1	6.1	22.2	14.3	...	23.6	...	6.1	...	3.2	10.6	A. d. E. 1861, p. 119.
Do	47.9	42.2	8.4	4.6	29.2	15.6	...	22.5	...	3.9	...	3.5	13.0	A. B. d. B., No. 1897.
Wiker, Erdmanns Schacht	41.8	35.7	7.7	6.7	31.1	18.8	...	19.0	...	3.6	...	4.2	14.3	A. d. E., 1867, p. 151.
Do	41.5	38.4	7.7	8.3	32.7	12.9	...	20.5	...	3.6	...	2.9	15.4	A. d. E., 1871, p. 364.
Wilker, Ekertecklers Schacht	41.9	40.0	6.8	6.8	33.6	12.8	...	21.3	...	3.2	...	2.9	15.3	Do.
Dalkarlsberg, Flint-Grube, Erz No. 1	61.2	55.5	6.1	12.0	25.8	0.6	...	29.6	...	2.8	...	0.1	13.7	
Dalkarlsberg, Flint-Grube, Erz No. 2	54.4	57.0	5.7	8.6	28.0	0.7	...	30.4	...	2.7	...	0.2	13.6	
Dalkarlsberg, Lång-Grube, Erz No. 1	56.8	51.1	8.4	13.0	26.5	1.0	...	27.2	...	3.9	...	0.2	14.3	
Dalkarlsberg, Läng-Grude, Erz No. 2	48.5	52.6	9.7	9.2	27.6	0.9	...	28.0	...	4.5	...	0.2	13.5	
Dalkarlsberg, Österrymning	61.2	45.9	30.8	7.9	13.3	2.1	...	24.5	...	14.4	...	0.5	7.5	A. d. E., 1860, p. 357.
Dalkarlsberg, Herr-Grube	64.1	46.3	21.8	12.2	17.5	2.2	...	24.7	...	10.2	...	0.5	10.4	A. d. E., 1860, p. 356.
Dalkarlsberg, Ny-Grube, Erz No. 2	50.1	56.3	8.1	8.5	25.7	1.4	...	30.0	...	3.8	...	0.3	12.7	A. d. E., 1869, p. 221.
Dalkarlsberg, Åkers-Grube, Erz No. 1	58.4	62.9	9.1	7.2	18.9	1.9	...	33.5	...	4.2	...	0.4	9.6	A. d. E., 1868, p. 410.
Dalkarlsberg, Orm-Grube, Erz No. 1	58.0	57.5	16.2	3.7	21.8	0.8	...	30.7	...	7.5	...	0.2	10.0	A. d. E., 1869, p. 221.
Dalkarlsberg, Fall-Grube	65.9	49.3	16.5	5.5	22.4	6.3	...	26.3	...	7.7	...	1.4	10.5	A. d. E., 1867, p. 151.
Dalkarlsberg, Fall-Grube, Erz No. 2	58.2	62.1	10.4	2.8	23.2	1.5	...	33.1	...	4.8	...	0.3	10.0	A. d. E., 1866, p. 287.
Rödberg	63.2	63.2	14.5	7.9	12.8	1.6	...	33.7	...	6.8	...	0.4	7.3	
Mo-Grube	68.3	55.2	17.3	7.6	19.2	0.7	...	29.4	...	8.1	...	0.2	9.8	
Parish Winteråsa.														
Sanna	45.3	23.2	0.3	26.1	28.1	22.3	...	12.4	...	0.1	...	5.0	18.7	
Parish Knista.														
Nyberg, Prima Erz	53.5	44.0	6.0	7.3	8.6	34.1	...	23.5	...	2.8	...	7.7	5.5	A. B. d. B., No. 1886.
IN THE PROVINCE OF WERMLAND.														
Parish Gåsborn.														
Fagerberg	50.0	45.3	8.7	32.8	6.2	7.0	...	24.2	...	4.0	...	1.6	11.8	A. d. E., 1863, p. 268.
Do	54.4	44.1	4.0	24.4	20.2	7.3	...	23.5	...	1.9	...	1.6	15.0	
Do	46.1	49.8	6.3	23.4	16.1	4.4	...	26.6	...	2.9	...	1.0	13.1	
Hammar	50.8	70.2	6.2	1.7	21.0	0.9	...	37.4	...	2.9	...	0.2	8.9	A. d. E., 1864, p. 209.
Parish Nordmark.														
Taberg, nördlicher	56.3	57.4	7.2	10.5	23.7	1.2	...	30.6	...	3.4	...	0.3	12.4	A. d. E., 1863, p. 243.
Taberg, kleiner	53.4	59.5	5.6	11.2	23.1	0.6	...	31.7	...	2.6	...	0.1	12.4	Do.
Do	51.3	61.2	2.2	11.4	24.0	1.2	...	32.6	...	1.0	...	0.3	12.8	A. d. E., 1872, p. 225.
Nordmark, Berg-Grube	55.2	56.2	5.8	17.2	18.6	2.2	...	30.0	...	2.7	...	0.5	12.3	A. d. E., 1863, p. 243.
Nordmark, Ko-Grube	54.1	53.6	3.6	22.2	18.8	1.8	...	28.6	...	1.7	...	0.4	13.8	A. d. E., 1872, p. 226.

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
PROVINCE OF WERMLAND—Continued.														
Parish Nordmark.														
Nordmark, Grundsjö und Brattfors	59.8	56.9	4.1	22.7	13.4	2.9	......	30.3	......	1.9	......	0.7	11.8	A. d. E. 1863, p. 243.
Finnmossen	60.7	52.3	6.8	15.5	22.8	2.6	......	27.9	......	3.2	......	0.6	13.5	A. d. E. 1872, p. 225.
Parish Fernebo.														
Långban, Sicilien	62.6	80.8	5.4	5.9	7.9	Trace	......	43.1	......	2.5	......	......	4.8	A. d. E. 1863, p. 243.
Persberg, Kran-Grube	50.1	58.1	9.5	14.2	18.1	0.1	......	31.0	......	4.4	......	0.02	11.3	A. d. E. 1852, p. 190.
Persberg, Skärstöten	54.3	55.5	10.0	6.3	28.1	0.1	......	29.6	......	4.7	......	0.02	13.0	Do.
Persberg, Torskebäck	55.2	57.5	3.7	23.0	15.6	0.2	......	30.7	......	1.7	......	0.04	12.8	A. d. E. 1863, p. 243.
Persberg, Gustav Adolph	53.1	51.0	5.0	21.0	22.3	0.7	......	27.2	......	2.3	......	0.2	14.9	A. d. E. 1865, p. 237.
Persberg, Stor-Grube	53.1	57.1	11.2	11.9	19.6	0.2	......	30.4	......	5.2	......	0.04	11.2	A. d. E. 1852, p. 190.
Persberg, Jordåskärr	59.8	55.0	6.0	24.3	12.1	2.6	......	29.3	......	2.8	......	0.6	11.7	A. d. E. 1863, p. 243.
Persberg, Jordås	63.8	53.5	10.2	24.4	10.4	1.5	......	28.5	......	4.8	......	0.3	11.1	A. d. E. 1866, p. 287.
Persberg, Östra Hagen	56.2	62.8	3.1	15.1	19.0	Trace	......	33.5	......	1.4	......	......	11.9	A. d. E. 1863, p. 243.
Persberg, Väg-Grube	59.6	54.4	7.3	11.0	26.0	1.3	......	29.0	......	3.4	......	0.3	13.5	A. d. E. 1866, p. 287.
Persberg, Nord-Grube	54.2	58.7	3.1	13.7	23.5	1.0	......	31.3	......	1.4	......	0.2	13.3	A. d. E. 1863, p. 243.
Persberg, Nord-Grube, nördliche	52.7	64.2	2.1	5.1	28.1	0.5	......	34.4	......	1.0	......	0.1	12.7	A. d. E. 1866, p. 287.
Persberg, Dunderbacken	57.4	82.7	5.5	5.4	5.5	0.9	......	44.1	......	2.6	......	0.2	3.7	Do.
Högberg, Krakbo	56.0	55.7	3.9	33.2	6.5	0.7	......	29.7	......	1.8	......	0.2	12.1	A. d. E. 1863, p. 243.
Limkärn	51.8	53.9	4.3	32.3	8.0	1.5	......	28.7	......	2.0	......	0.3	12.4	Do.
Do.	54.1	45.8	15.8	29.0	6.7	2.7	......	24.4	......	7.4	......	0.6	10.9	A. d. E. 1864, p. 209.
Limkärn, südliche oder Nyårs-Grube	55.8	51.8	8.6	23.9	14.2	1.5	......	27.6	......	4.0	......	0.3	12.5	Do.
Kirkvik	49.4	52.8	8.0	24.5	13.1	1.6	......	28.1	......	3.7	......	0.4	12.2	A. d. E. 1868, p. 410.
Finshyttan, Eng-Grube	54.9	51.4	6.6	14.7	24.7	2.6	......	27.4	......	3.1	......	0.6	14.0	A. d. E. 1872, p. 225.
Age, Fahlbäck	51.2	54.5	4.4	17.2	20.5	3.4	......	29.1	......	2.0	......	0.8	13.1	A. d. E. 1861, p. 110.
Age, Lejel	46.3	51.2	11.3	14.4	19.8	3.3	......	27.3	......	5.3	......	0.7	12.0	A. d. E. 1861, p. 111.
Mörkhult, Hallsat-Grube	63.2	51.3	5.8	22.0	16.5	4.4	......	27.4	......	2.7	......	1.0	12.9	A. d. E. 1861, p. 113.
Morkhult, Mörkhult-Grube	54.7	56.0	5.8	24.4	12.3	1.5	......	29.9	......	2.7	......	0.3	11.9	A. d. E. 1861, p. 112.
Gås-Grube, Blanka	63.1	50.7	6.7	19.4	20.5	2.7	......	27.0	......	3.1	......	0.6	13.7	A. d. E. 1869, p. 221.
Nyttsta, Vret-Grube	58.3	50.6	6.4	6.4	35.3	1.3	......	27.0	......	3.0	......	0.3	15.9	A. d. E. 1867, p. 151.

Parish Kroppa.														
Dränke	52.5	54.4	7.6	16.2	21.0	0.8	....	29.0	......	3.5	......	0.2	13.0	
Tallholm	38.0	56.6	3.8	23.9	15.0	0.7	....	30.2	......	1.8	......	0.2	12.8	A. d. E. 1872, p.
IN THE PROVINCE OF SÖDERMANLAND.														
Parish Floda.														
Staf, alto	*38.6	78.3	6.2	6.7	5.9	2.9	....	41.8	......	2.9	......	0.7	4.3	A. d. E. 1860, p. 4[illegible]3.
Parish Sköldinge.														
Skalunda, Sophia	57.6	75.1	18.7	5.2	1.0	......	....	40.0	......	8.7	......	......	1.8	A. d. E. 1860, p. 513.
Wilhelmina	58.1	49.0	38.1	9.5	Trace.	1.8	1.6 per cent. Ti O^2 ..	26.1	0.6	17.7	......	0.4	2.7	A. d. E. 1860, p. 459.
Parish Åker.														
Skotvång	*37.1	85.2	1.3	7.4	5.4	0.7	....	45.4	......	0.6	......	0.2	4.3	A. d. E. 1864, p. 335.
Parish Gåsinge.														
Elgsjö	*49.8	84.5	4.1	4.8	4.1	2.5	....	45.1	......	1.9	......	0.6	3.0	A. d. E. 1864, p. 343.
Parish Svärtuna.														
Förola	*55.9	90.6	4.2	2.6	0.4	2.2	....	48.3	......	2.0	......	0.5	0.9	A. d. E. 1860, p. 399.
Do	50.1	79.0	3.8	4.7	11.7	0.8	....	42.1	......	1.8	......	0.2	6.0	
Gillinge	45.8	75.4	4.5	8.0	5.3	6.8	....	40.2	......	2.1	......	1.5	4.4	
Sjösa, Stor-Grube	*31.6	59.1	8.8	25.5	1.7	4.9	....	31.5	......	4.1	......	1.1	7.9	A. d. E. 1869, p. 354.
Parish Jerna.														
Jerna	*62.4	76.5	12.4	4.5	6.3	0.3	....	40.8	......	5.8	......	0.1	3.8	A. d. E. 1860, p. 411.
IN THE PROVINCE OF ÖSTERGÖTLAND.														
Parish Mogata.														
Petäng	*44.8	55.5	11.2	18.9	12.8	1.6	....	29.6	......	5.2	......	0.4	10.5	A. d. E. 1860, p. 423.
Parish Skällsvik.														
Nartorp, Prima Erz	*46.6	57.5	2.8	32.1	7.1	0.5	....	30.7	......	1.3	......	0.1	12.0	A. d. E. 1860, p. 505.
Do	*44.3	57.7	5.7	26.3	8.8	1.5	....	30.8	......	2.7	......	0.3	11.0	A. d. E. 1869, p. 361.
IN THE PROVINCE OF CALMAR.														
Parish Ukna.														
Stenebo	*54.7	80.4	9.6	3.2	5.2	1.6	....	42.9	......	4.5	......	0.4	3.0	A. d. E. 1860, p. 400.

Analyses of Swedish iron-ores—Continued.

Locality.	The amount of iron in the ore.	The amount of slag-forming constituents of the ore.						Oxygen content of the slag-forming constituents.						The analysis is given in—
		Silica.	Alumina.	Lime.	Magnesia.	Protoxide of manganese.	Other substances.	Silica.	Titanic acid or oxide.	Alumina.	Oxide of cerium and glucina.	Protoxide of manganese.	Lime and magnesia.	
IN THE PROVINCE OF JÖNKÖPING.														
Parish Månsarp.														
Taberg	31.5	39.8	10.4	3.1	34.2	0.7	11.8 per cent. $Ti\,O^2$	21.2	4.6	4.8	......	0.2	14.5	A. d. E. 1866, p. 143.
IN THE PROVINCE OF KRONOBERG.														
Parish Ryssby.														
Långhult	38.3	33.3	20.1	4.0	22.9	0.7	19.0 per cent. $Ti\,O^2$	17.8	7.4	9.4	......	0.2	10.3	A. d. E. 1866, p. 247.

* This per cent. of iron was not found in the ore itself, but in the product obtained by the crucible-assay, 96 per cent. of the weight of the regulus being added to the iron found in the slag, and the per cent. of oxide in the ore being reckoned from the amount of metallic iron thus found.

† The per cent. of protoxide of manganese was not found in the ore itself, but was reckoned from the amount found in the slag, when the crucible-assay was made with the most acid mixture possible. The numbers inclosed in parentheses do not indicate the amounts found in the ore itself, but the percentages found in the regulus, when the crucible-assay was made with the most acid mixture possible.

CHAPTER VI.

SPAIN, RUSSIA, AND SIBERIA.

SPANISH IRON-MINES; ARRANGEMENT OF THE OBJECTS; EXTENT AND CONDITION OF THE IRON-INDUSTRY OF THE RUSSIAN EMPIRE IN 1871; IMPORTS AND EXPORTS; PRODUCT OF IRON-ORES AND OF CAST IRON; IRON AND STEEL; LIST OF IRON-WORKS IN THE RUSSIAN EMPIRE; PRODUCTION OF COAL; LIST OF COLLIERIES; PETROLEUM AND CHROMIC IRON; OTHER MINERALS AND METALS.

148. SPAIN.—A number of the iron-mines of Spain were represented by samples. It is well known that a large amount of money has been invested in Spanish iron-mines by British capitalists. Although it has been provided by legislative authority that no export duty shall be imposed upon ores before the year 1881, an attempt was made to collect a duty of about 25 cents a ton, but this failed through the protests of the English, French, and German governments. A duty of about 13 cents is exacted by the municipality of Bilbao. The capacity of production and of export of Spanish ores is important to the iron-industry of the United States, especially as a certain amount of these ores are imported for the manufacture of spiegel iron.

The number and distribution of the iron-mines of Spain, together with the production for the years 1869 and 1870, are shown in the following tabular statement:

Provinces.	1869.		1870.	
	No. of mines.	Produce in quintals.	No. of mines.	Produce in quintals.
Almeria	6	87, 200	6	87, 600
Badajcs	6	24, 000	6	28, 000
Biscay	75	1, 648, 000	75	2, 503, 575
Búrgos	2	3, 318	3	7, 500
Córdoba	1	4, 000	1	2, 000
Gerona	2	2, 238	8	1, 962
Guadalajara	4	4, 651	......	....
Guipúzco	29	184, 970	29	159, 000
Levu	10	13, 950	10	9, 319
Logroño	5	36, 320	5	18, 029
Lugo	1	9, 443	1	10, 880
Malaga	7	103, 860	8	200, 070
Múrcia	14	135, 500	14	157, 528
Navarre	8	114, 740	8	77, 640
Orense	1	5, 359	......	....
Oviedo	56	335, 492	49	694, 525
Santander	36	345, 387	29	352, 420
Seville	6	32, 077	6	32, 392
Tarragona	3	500	1	250
Teruel	2	8, 400	2	11, 000
Toledo	3	14, 000	6	12, 180
Total	......	3, 113, 405	......	4, 365, 870

149. THE IRON-MANUFACTURES OF RUSSIA.—The iron and steel display from Russia is arranged very tastefully in the alcoves between the high columns of the main nave. Upon a crimson-cloth background, surmounted by a gilded imperial crown, the manufactures of the imperial works, consisting of sword-blades and other material of war, are skillfully displayed, as if they were trophies. Parts of cannon, steel shot and shell, chain-cables, rails, and bar-iron are grouped at the base, together with huge masses of the ore. The display by Pontiloff is similarly arranged, but consists chiefly of steel and iron rails radially disposed above a monumental mass of ores. In Prince Demidoff's exhibition the iron-ores are grouped with polished masses of malachite. Broken steel ingots, and copper ingots, also broken to show the grain, stand side by side. There is also a fine group of polished iron rods, tied in knots, without showing a crack or flaw, and of rails twisted into ringlets, to prove their extreme toughness and uniformity.

The famous sheet-iron of the country is shown in sheets of all sizes and degrees of thickness, and specimens the size of visiting-cards have been freely distributed. Among the more instructive and novel parts of the collections are models of iron-works showing the roofs supported upon a series of semicircular iron arches springing from the level of the floor; a series of drawings of Rachette's furnaces, and maps showing the extent of the mineral industries of the empire. The iron-metallurgists of Russia are not behind those of Europe in the introduction of new and improved methods. Great advances have been made in the production of cast steel on a large scale, and in the manufacture of steel guns of large caliber, several of which are exhibited from the works of Oboukoff. The largest is a 12-inch rifled breech-loader, weighing 81,000 pounds. There are fine groups of railway tires, axles, and other railroad-material, from the same establishment. Rachette's system of furnaces is extensively used, and is said to give remarkable results. The Bessemer and Siemens-Martin processes, for the production of steel, are successfully introduced.

149. *Statistics.*—An interesting *résumé*, by the mining engineer Skalkovsky, of the mining-industry of Russia, with statistical tables of the production of iron and other metals, was distributed by the Russian commission,* and is the source of the following data and general observations. The iron-industry was diminishing. In 1870 there were 1,283 works in operation, and 1,174 in 1871. Of steel, 536,086 pounds were produced in 1870, and 442,241 in 1871. The production of cast iron was slightly greater in 1871 than in 1870, as shown in the following table, giving a general view of the extent and condition of the iron-industry of Russia in 1870 and 1871:

	1870.	1871.
Cast iron, (pouds†)	21,959,326	22,004,518
Wrought iron, (pouds)	15,217,908	14,958,597

* *Tableaux statistiques de l'Industrie des Mines en Russie en 1871, par C. Skalkovsky, Ingénieur des Mines.* St. Petersburg, 1873. 8vo., pamphlet, pp. 40.

† The Russian poud is equivalent to 16.3808 kilograms.

	1870.	1871.
Steel, (pouds)	536, 086	442, 241
Iron and steel works, (number)	214	214
High furnaces, (number)	245	222
Puddling furnaces, (number)	445	431
Refining-furnaces, (number)	692	667
Forges, (number)	924	818
Steel-furnaces, (number)	495	372

The imports and exports of iron and steel in 1872 were as follows:

	Imports, pouds.		Exports, pouds.	
	Europe.	Asia.	Europe.	Asia.
Cast iron	2, 923, 305	....	14, 947	....
Wrought iron	13, 890, 817	5	262, 714	46, 084
Steel	812, 355	4, 211	....	4, 853

A full list is given of the iron-works of the empire, with their production for the year 1871. The two following tabular statements are condensed from the list:

Table of production of iron-ore and of cast iron in the Russian Empire in 1871, (*in pouds.*)

[One Russian poud = 16. 3808 kilograms.]

No. of works.	Establishments.	Ores extracted.	Ore and slag smelted.	Cast iron. Pig-iron.	Cast iron. Various objects.
12	Pertaining to the crown	4, 216, 593	5, 055, 954	2, 120, 121	150, 370
2	Cabinet of His Imperial Majesty	142, 300	161, 720	50, 661	11, 051
55	Private works, Ural	27, 094, 488	25, 287, 043	11, 181, 017	1, 807, 436
26	Private works about Moscow	8, 381, 938	7, 147, 711	2, 309, 725	855, 238
1	Private works, Caucasus	53, 671	69, 862	8, 180	10, 803
8	Private works, western and southern provinces	1, 370, 512	1, 373, 587	323, 729	22, 348
2	Private works, Siberia	538, 903	538, 903	274, 581	30, 888
3	Crown works, kingdom of Poland	1, 058, 115	593, 470	177, 863	26, 630
31	Private works, kingdom of Poland	5, 444, 397	5, 261, 453	1, 178, 576	235, 111
15	Private works, Finland	2, 522, 751	3, 077, 449	1, 230, 181	....
	Grand totals	50, 823, 668	48, 567, 152	18, 854, 634	3, 149, 875
				22, 004, 509	

Table of production of iron and steel in the Russian Empire in 1871, (*in pouds.*)

[One Russian poud = 16. 3808 kilograms.]

No. of works.	Establishments.	Bar-iron.	Sheet-iron.	Steel.
13	Crown works	585, 385	139, 529	112, 070
2	Cabinet of His Imperial Majesty	17, 108	1, 220	251
98	Private works, Ural	5, 254, 076	2, 456, 192	70, 975
19	Private works about Moscow	1, 650, 864	106, 011	....
1	Private works, Caucasus	1, 217	....	....
2	Private works, Siberia	123, 381	16, 932	616
13	Works not under the mining administration	2, 648, 818	228, 198	193, 704
4	Crown works, Poland	129, 960	1, 055	....
36	Private works, Poland	890, 524	48, 278	....
25	Private works, Finland	658, 289	1, 560	64, 625
	Total	11, 959, 622	2, 998, 975	442, 241

The Russian Mining Journal, 1872, presents a statement of the production of cast and wrought iron in the Ural district for each successive ten years, commencing from 1797, as follows: *

Period.	Cast iron.		Wrought iron.	
	Pouds.	Tons.	Pouds.	Tons.
1797–1807	6, 435, 342	103, 794	3, 820, 067	61, 613
1807–1817	6, 307, 108	101, 743	3, 993, 144	64, 405
1817–1827	6, 836, 560	110, 268	4, 568, 263	73, 681
1827–1837	7, 549, 167	121, 760	4, 987, 351	80, 441
1837–1847	8, 413, 758	136, 028	5, 830, 761	94, 044
1847–1857	9, 923, 467	160, 055	7, 046, 205	113, 648
1857–1867	12, 480, 827	201, 303	8, 021, 561	129, 380

150. Iron-works in the Russian Empire.—The following is a list of the imperial, royal, and private iron-works in the Russian Empire, with their production of iron and steel in the year 1871: †

Production of iron-ore and of cast iron.

Works.	Iron-ore mined.	Iron ore and slag smelted.	Production of cast iron.	
			Pig-iron.	Various objects.
A.—*Crown works.*	*Pouds.*	*Pouds.*	*Pouds.*	*Pouds.*
1. Kamensky	562, 500	512, 598	162, 335	49, 814
2. Zlatooustofsky	259, 865	252, 268	109, 798	6, 655
3. Satkinsky	400, 000	648, 002	305, 959	5, 763
4. Koucinsky	350, 000	420, 011	151, 259	21, 218
5. Kouchvinsky		1, 012, 235	531, 106	19, 933
6. Barantchinsky	2, 039, 345	585, 891	325, 342	17, 712
7. Verkhnié-Tourinsky		291, 295	158, 787	1, 705
8. Peskovsky	480, 521	869, 850	240, 278	23, 528
9. Licitchansky	23, 543	94, 374	30, 972	....
10. Kontchosersky	....	75, 297	21, 386	66
11. Souôiarvsky	100, 819	164, 775	42, 905	3, 816
12. Valazminsky	....	129, 358	39, 894	169
Total	4, 216, 593	5, 055, 954	2, 120, 121	150, 379
B.—*Works pertaining to the cabinet of the Emperor.*				
13. Gouriévsky	42, 300	47, 770	19, 117	1, 724
14. Pétrovsky	100, 000	113, 950	31, 544	9, 317
Total	142, 300	161, 720	50, 661	11, 051
C.—*Private work, Ural.*				
15. Nigenié Saldinsky		27, 633	13, 428	3, 253
16. Nigenié-Taghilsky	4, 565, 327	1, 471, 628	806, 064	163, 604
17. Verkhnié-Saldinsky		1, 256, 023	691, 076	117, 142
18. Vicimo-Chaïtansky		521, 826	321, 536	22, 281
19. Verkh-Isetsky	184, 850	348, 629	173, 968	31, 548
20. Réjevskoï	180, 972	489, 352	261, 408	27, 550
21. Verkhniéneïvinsky	10, 000	131, 389	65, 571	8, 874
22. Neïvinskoroudiansky	205, 000	404, 809	215, 190	31, 891
23. Verkhnié-Taghilsky	128, 215	518, 811	260, 878	46, 866
24. Outkinsky, (Jakovlev)	140, 000	321, 794	119, 756	66, 614
25. Néïvo Alapaïevsky	1, 053, 458	1, 055, 458	477, 333	37, 917
26. Néïvo Chaïtansky	378, 262	378, 262	186, 323	23, 947
27. Verkhnié-Siniatchikhinsky	558, 764	558, 764	248, 739	13, 492
28. Néviansky	799, 981	575, 934	265, 086	43, 699
29. Pétrokamensky	260, 941	244, 566	104, 946	24, 997
30. Nigenié-Serghinsky	475, 894	382, 760	148, 231	22, 480
31. Verkhnié-Serghinsky	526, 250	297, 683	116, 521	8, 843
32. Kychtymsky	821, 508	597, 449	264, 237	52, 000
33. Kaslinsky	462, 224	338, 270	167, 750	15, 091
34. Niasépétrovsky	544, 970	303, 386	120, 011	40, 252
35. Sycertsky	1, 436, 570	1, 087, 204	522, 005	40, 599
36. Siéversky	517, 000	493, 851	200, 654	59, 473
37. Molebsky	279, 722	245, 277	105, 370	15, 818
38. Outkinsky, (Souksounsky)	410, 160	463, 906	208, 257	23, 712

*Cited in Jour. Iron and Steel Institute, by David Forbes, F. R. S., &c. I, 1873, p. 221.
† From Skalkovsky's *Tableaux statistiques*, at the Vienna Exhibition.

Production of iron-ore and of cast iron—Continued.

Works.	Iron-ore mined.	Iron-ore and slag smelted.	Production of cast iron.	
			Pig-iron.	Various objects.
C.—*Private work, Ural*—Continued.	*Pouds.*	*Pouds.*	*Pouds.*	*Pouds.*
39. Revdinsky	676, 036	676, 036	349, 403	22, 101
40. Chaïtansky	320, 227	320, 227	120, 138	29, 612
41. Nigenié-Irghinsky	186, 937	150, 891	40, 616	13, 463
42. Vciévolodovilvensky	251, 115	226, 776	70, 568	....
43. Alexandrovsky	263, 400	208, 303	62, 646	7, 277
44. Tchermosky	735, 268	250, 993	108, 280	21, 210
45. Kiselovsky		609, 949	290, 960	22, 010
46. Arghangelo-Pachyisky, (1870)	668, 998	616, 797	211, 705	69, 214
47. Koucié-Alexandrovsky, (1870)	443, 303	490, 735	178, 121	28, 036
48. Kynovskoï	229, 735	425, 609	152, 733	44, 057
49. Bilimbaïevsky	804, 554	934, 242	381, 163	88, 256
50. Kouvinsky, (1870)	495, 960	744, 856	291, 319	24, 372
51. Lysvensky	359, 902	276, 956	98, 461	14, 975
52. Bicersky	292, 986	226, 994	93, 927	7, 327
53. Verkhnié-Oufaléïsky	713, 008	544, 533	269, 097	23, 825
54. Nigenié-Oufaléïsky	661, 615	574, 522	233, 249	55, 143
55. Jourusansky	523, 000	478, 404	253, 207	38, 749
56. Katav-Ivanovsky	1, 026, 490	847, 622	427, 530	83, 163
57. Simsky	747, 324	460, 535	204, 730	56, 322
58. Nicolaévsky		209, 568	69, 318	49, 420
59. Biéloretsky	499, 110	280, 725	146, 607	34, 705
60. Tirlansky		186, 673	105, 649	10, 167
61. Verkhnié-Avsianopétrovsky	560, 000	546, 624	226, 373	33, 774
62. Omoutninsky	1, 195, 097	1, 072, 116	325, 997	29, 786
63. Verkhnié-Zalazninsky	350, 382	136, 342	37, 681	6, 279
64. Zalazninsko-Biéloretsky	....	160, 954	30, 633	....
65. Klimkovsko-Borovskoï	624, 100	557, 452	175, 144	34, 379
66. Tchernokholounitsky	405, 772	443, 689	142, 573	13, 790
67. Chourmonikolsky	21, 163	....	....	....
68. Nioutchpasky	72, 448	50, 515	12, 944	1, 060
69. Niouvchimsky	26, 490	27, 642	5, 935	3, 021
Total	27, 094, 488	25, 287, 043	11, 181, 017	1, 807, 436
D.—*Private works around Moscow.*				
70. Vyksounsky	1, 145, 765	790, 718	328, 842	13, 999
71. Snovedsky		669, 652	265, 713	....
72. Oungensky	51, 100	65, 676	23, 543	....
73. Gouciévsky	229, 852	272, 990	92, 719	13, 074
74. Verkhnié-Oungensky	140, 000	136, 085	54, 172	3, 485
75. Ilevskoï	862, 800	809, 085	382, 816	24, 155
76. Tâchinsky	312, 019	324, 811	153, 506	4, 048
77. Karatcharovsky	390, 000	387, 936	178, 106	6, 662
78. Merdouchinsky	295, 000	235, 032	88, 030	7, 245
79. Dougnensky	212, 315	195, 812	56, 942	51, 820
80. Récetinsky	190, 819	105, 819	21, 929	13, 402
81. Sénetsko-Ivanovsky	268, 294	177, 296	37, 493	32, 057
82. Lioudinovsky	1, 425, 000	736, 693	160, 705	172, 229
83. Soukremensky				
84. Ivano-Serghievsky	350, 000	247, 169	80, 826	12, 173
85. Pessotchinsky, (de Maltzof)	432, 128	403, 175	77, 380	96, 434
86. Pessotchinsky, (de Krivorotof)	232, 035	193, 998	28, 161	62, 375
87. Tchérépetsky	145, 956	144, 313	44, 573	40, 486
88. Bogdano-Pétrovsky	107, 900	105, 708	27, 942	22, 332
89. Mychegsky	378, 000	336, 268	47, 025	108, 935
90. Cyntoulsky	350, 000	251, 178	46, 915	46, 765
91. Istinsko-Zalipiagesky	125, 000	109, 162	32, 966	14, 478
92. Bytochevsky	172, 383	161, 331	26, 472	32, 927
93. Avgarsky	10, 500	....	....	....
94. Doubensky	155, 072	240, 675	42, 686	75, 547
95. Sentoursky	100, 000	21, 129	10, 263	700
Total	8, 381, 938	7, 147, 711	2, 309, 725	855, 238
E.—*Private works, Caucasus.*				
96. Tchatakhsky	53, 671	69, 862	8, 180	10, 803
F.—*Private works, western and central provinces.*				
97. Sociét. de la Nouvelle Russie	163, 289	163, 289	34, 472	....
98. Kletishtchensky	619, 700	494, 100	128, 099	4, 080
99. Roudnia		125, 600	35, 280	....
100. Dénéchovsky	12, 000	(?)14, 000	10, 000	5, 975
101. Alexandra	450, 673	450, 673	88, 298	....
102. Vysòkaïa Petche	5, 600	6, 675	3, 600	2, 553
103. Goutka	111, 200	111, 200	20, 200	8, 000
104. Dans de pet. usines	8, 050	8, 050	3, 780	1, 740
Total	1, 370, 512	1, 373, 587	323, 729	22, 348

Production of iron-ore and of castiron—Continued.

Works.	Iron-ore mined.	Iron-ore and slag smelted.	Production of cast iron.	
			Pig-iron.	Various objects.
G.—*Private works, Siberia.*				
	Pouds.	*Pouds.*	*Pouds.*	*Pouds.*
105. Abakansky	338, 571	338, 571	167, 132	22, 693
106. Nikolaïévsky	200, 332	280, 332	107, 449	8, 195
Total	538, 903	538, 903	274, 581	30, 888
H.—*Works of the crown, kingdom of Poland.*				
107. Bankovsky	284, 220	291, 217	97, 369	5, 105
108. Pankovsky	112, 885	99, 397	32, 638	11, 351
109. Réïefsky	661, 010	202, 860	47, 856	10, 174
Total	1, 058, 115	593, 470	177, 863	26, 630
J.—*Private works, kingdom of Poland.*				
110. Ostrovetzky	450, 000	453, 634	120, 000	5, 000
111. Strakovitzky	800, 000	500, 000	140, 141	9, 963
112. Falkovsky	111, 250	111, 250	20, 300	2, 825
113. Khmelevsky	200, 000	150, 000	30, 000	15, 000
114. Bodsekovsky	160, 000	155, 000	40, 000	3, 500
115. Drzevitzky	308, 900	302, 840	25, 605	30, 125
116. Przisoukskу	166, 375	153, 125	37, 125	......
117. Bialatchevsky	45, 687	136, 862	22, 075	10, 517
118. Koritkovsky	146, 000	146, 000	29, 200	......
119. Malenetzky	202, 718	229, 161	41, 615	4, 870
120. Makhorakskу	152, 857	152, 521	35, 590	......
121. Rzouzovsky	175, 600	162, 700	38, 520	......
122. Blizinsky	93, 940	82, 208	7, 002	13, 550
123. Ninkovsky	133, 500	133, 500	28, 000	......
124. Khlevissky	592, 286	700, 936	158, 144	5, 697
125. Neclansky	177, 862	231, 962	66, 747	3, 131
126. Borkovitzky	203, 550	196, 800	42, 165	......
127. Konsky	382, 935	346, 850	95, 712	2, 104
128. Krasniensky	40, 600	90, 600	11, 754	6, 070
129. Chtchezinsky	98, 550	72, 750	11, 250	8, 562
130. Fidor	53, 000	53, 000	21, 750	......
131. Okrad zénov	......	?	45, 000	......
132. Poremba Mziglozka	14, 400	?	38, 551	......
133. Maslonsk	......	......	......	......
134. Miatchev	9, 000	(?)21, 000	20, 000	......
135. Bliakhovnia	151, 810	218, 393	330	53, 822
136. Staraia Kousnitza	204, 979	204, 979	5, 000	35, 000
137. Inovlodz	80, 000	76, 000	21, 000	......
138. Przistan	76, 250	76, 650	6, 000	25, 375
139. Goustek	......	102, 732	20, 000	......
140. Mines of Vélune and Bendine, (1870)	212, 347	......	......	......
Total	5, 444, 397	5, 261, 453	1, 178, 576	235, 111
K.—*Private works, Finland.*				
141. Tiké		225, 565	114, 592	......
142. Koskis		130, 332	49, 920	......
143. Dals		357, 565	181, 627	......
144. Hegfors		63, 999	19, 050	......
145. Skegbi		70, 467	27, 483	......
146. Soumboula		20, 904	7, 150	......
147. Vertsilé		434, 980	162, 605	......
148. Mekhké	2, 522, 751	382, 236	146, 006	......
149. Stremsdal		167, 762	53, 206	......
150. Loupikko		375, 928	137, 355	......
151. Kartula		215, 238	66, 643	......
152. Irkakoski		51, 095	21, 247	......
153. Ekatérinensky		146, 244	50, 669	......
154. Haapakosky		218, 452	87, 450	......
155. Oravi		238, 692	105, 178	......
Total	2, 522, 751	3, 077, 449	1, 230, 181	......
Grand total	50, 823, 668	48, 567, 152	18, 854, 634	3, 149, 884
Grand total of cast iron	......	......	22, 004, 518	

Production of iron, and of steel.

Works.	Iron in bars and rods.	Sheet-iron of all kinds.	Steel, cast and hammered.
A.—*Crown works.*	*Pouds.*	*Pouds.*	*Pouds.*
1. Nigenié-Icetsky	67, 703	12, 852	....
2. Zlatooust Kniasé-Mikhaïlovsky	11, 423	....	....
3. Koucinsky	13, 567	....	....
4. Satkinsky	....	....	44, 778
5. Artinsky	41, 328	....	1, 417
6. Nigenié-Tourinsky	51, 479	33, 835	459
7. Sérébriansky	79, 324	....	....
8. Permsky stalepouchetchny	....	4, 763	64, 440
9. Votkinsky	157, 946	71, 560	976
10. Kamsky	111, 393	5, 402	....
11. Kirsinsky	134, 705	11, 117	....
12. Lougansky	14, 469	....	....
13. Alexandrovsky	2, 048	....	....
Total	585, 385	139, 529	112, 070
B.—*Works pertaining to the cabinet of the Emperor.*			
15. Gourievsky	8, 643	....	....
16. Pétrovsky	8, 465	1, 220	251
Total	17, 108	1, 220	251
C.—*Private works, Ural.*			
17. Nigenié-Taghilsky 18. Laisky	....	254, 934	15, 552
19. Nigenié-Saldinsky 20. Verkhnié-Saldinsky	448, 292	915	11, 956
21. Vicimôoutkinsky 22. Visimochaitansky	218, 427	....	....
23. Tschernôistotchinsky	34, 282	262, 855	....
24. Verkhnié-Isetsky	2, 930	102, 034	5, 601
25. Réjevskoï	16, 485	219, 367	....
26. Verkhnié-Néïvinsky 27. Nigeny-Verkhnié-Néïvinsky	291	131, 618	....
28. Néivinsko-Roudiansky 29. Nigeny-Roudiansky 30. Molebskoï	201	....	....
31. Chouralinsky 32. Verkhnié-Taghilsky 33. Vogoulsky	337	....	....
34. Outkinsky 35. Schaitansky	3, 501	2, 350	....
36. Sylvensky 37. Sarghinsky	1, 696	....	....
38. Néïvo-Alapaïevsky 39. Verkhnié-Siniatchikhinsky	232, 503	156, 678	....
40. Néïvo-Chaïtansky	824	226, 441	....
41. Irbitsky	18	....	....
42. Néviansky	126, 447	....	....
43. Pétrokamensky	134, 927	....	....
44. Nigenié-Serghinsky	48, 625	....	....
45. Verkhnié-Serghinsky	116, 244	....	....
46. Kosinsky	395	....	....
47. Atigsky	268	....	....
48. Mikhaïlovsky	195, 182	....	....
49. Kychtymsky	219, 485	....	....
50. Kaslinsky	15, 622	45, 213	....
51. Niasépétrovsky	10, 426	112, 207	....
52. Chemakhinsky	12, 826	....	....
53. Sycertsky	271, 744	....	....
54. Iliinsky 55. Polevskoy	57, 425	42, 790	....
56. Verkh-Sycertsky	166, 462	....	....
57. Siéversky	39, 288	....	....
58. Souksounsky	28, 566	....	....
59. Tissovsky	23, 104	....	....
60. Kambarsky	18, 093	17	....
61. Outkinsky	41, 043	....	....
62. Molebsky	3, 749	....	....
63. Revdinsky	177, 386	....	....
64. Bissertsky	125, 457	....	....
65. Rojestvensky	47, 337	....	....

Production of iron, and of steel—Continued.

Works.	Iron in bars and rods.	Sheet iron of all kinds.	Steel, cast and hammered.
C.—*Private works, Ural*—Continued.	*Pouds.*	*Pouds.*	*Pouds.*
66. Chaïtansky	58, 583	7, 340	....
67. Irghinsky	46, 013	....	....
68. Saraninsky	19, 401	....	....
69. Knaoufsky	5, 942	....	....
70. Pojevskoï	1, 625	74, 150	....
71. Elisavéto-Pojevskoï	....	56, 800	....
72. Vsiévolodovilvensky	1, 115	....	....
73. Alexandrovsky	4, 731	....	....
74. Nikitinsky	....	142, 360	....
75. Tchermosky	45, 745	148, 541	....
76. Kisélovsky			....
77. Polazninsky	107, 409	....	....
78. Khokhlovsky	38, 761	....	....
79. Kynovskoï	28, 077	70, 152	....
80. Bilimbaïëvsky	4, 496	....	....
81. Dobriansky	....	....	....
82. Sophyisky		....	....
83. Nytvensky	183, 749	....	....
84. Otchersky, (1870)	15, 461	....	....
85. Pavlovsky, (1870)	....	212, 278	....
86. Lysvensky	195, 738	....	....
87. Bicersky	33, 391	....	....
88. Kousié-Alexandrovsky, (1870)	2, 136	....	....
89. Archangelo-Pachiysky, (1870)	43, 809	....	....
90. Jougokamsky, (1870)	67, 138	517	....
91. Verkhnié-Oufaléïsky	10, 225	....	....
92. Nigenié-Oufaléïsky	215, 765	....	....
93. Jouruzansky	140, 440	....	10, 019
94. Minsky	1, 173	....	1, 232
95. Kataf-Ivanovsky	250, 771	23, 206	11, 986
96. Oust-Katafsky	108, 017	....	4, 239
97. Simsky	40, 303	....	3, 808
98. Miniarsky	160, 262	2, 249	....
99. Biéloretsky	144, 620	....	....
100. Tirliansky	58, 645	....	....
101. Verkhnié-Avsianopétrovsky	84, 983	....	....
102. Nigenié-Avsianopétrovsky	81, 281	....	....
103. Kajimsky	136	....	....
104. Nioutchpasky	701	....	....
105. Niouvtchimsky	5, 837	....	....
106. Omoutninsky	117, 137	28, 111	....
107. Poudemskoï	2, 048	33, 935	....
108. Zalazninsky	25, 258	....	....
109. Nigenié-Zalazninsky	23, 347	....	....
110. Kholounitsky	128, 875	99, 134	166
111. Bogorodsky			
112. Tchernokholounitsky	3, 396	....	....
113. Chourminsky	16, 156	....	....
114. Bouïsky	35, 492	....	....
Total	5, 254, 076	2, 456, 192	70, 975
D.—*Private works around Moscow.*			
115. Gousievskoï	69, 567	....	....
116. Vyksounsky	302, 421	8, 799	....
117. Snovedsky	24, 005	....	....
118. Verkhniégélieznitsky	109, 307	....	....
119. Véletminsky	140, 810	....	....
120. Doschato-Gélieznitsky	30, 294	38, 280	....
121. Jéremchinsky	24, 278	....	....
122. Merdouchinsky	55, 950	....	....
123. Karatcharovsky	133, 855	....	....
124. Ilevsky	253, 550	....	....
125. Voznécensky			....
126. Tachinsky	80, 090	....	....
127. Lioudinovsky	279, 581	57, 595	....
128. Soukremensky			....
129. Ivano-Serghievsky	71, 786	1, 337	....
130. Pessotchinsky, (of M. Maltzof)	8, 774	....	....
131. Sérensky	23, 051	....	....
132. Istinsko-Zalipiagesky	10, 977	....	....
133. Pétrovsky	8, 068	....	....
134. Sentourisky	24, 500	....	....
Total	1, 650, 864	106, 011	....

Production of iron, and of steel—Continued.

Works.	Iron in bars and rods.	Sheet-iron of all kinds.	Steel, cast and hammered.
E.—*Private works, Caucasus.*	*Pouds.*	*Pouds.*	*Pouds.*
135. Tchatakhsky	1, 217		
F.—*Private works, Siberia.*			
136. Abakansky	72, 945	12, 234	380
137. Nicolaiëvsky	50, 436	4, 698	236
Total	123, 381	16, 932	616
G.—*Works not under the jurisdiction of the administration of mines.*			
138. Ijorsky de l'Amirauté	18, 481	32, 508	
139. Oboukhovsky de l'Amirauté			142, 369
140. Ijevsky (Ministre de la Guerre)	41, 508		5, 735
141. Nevsky	131, 015	160, 500	
142. Arkadia 143. De M. Poutilof	1, 399, 019		
144. Grande société des chemins de fer	696, 873	7, 793	
145. Sormovsky	127, 731	27, 397	
146. Nicolsky	39, 055		
147. De M. G. Roukavichnikof			20, 500
148. De Th. S. Piatof			25, 100
149. Kletichtchensky	117, 987		
150. Alexandra	71, 715		
151. Small establishments	5, 434		
Total	2, 648, 818	228, 198	193, 704
H.—*Works of the crown, kingdom of Poland.*			
152. Soukhodnief	1, 740		
153. Selpia	74, 509		
154. Bankovsky	53, 223		
155. Slavkof	488	1, 055	
Total	129, 960	1, 055	
I.—*Private works, kingdom of Poland.*			
156. Ostrovetzky	3, 000		
157. Strakhovitzky	175, 056	3, 750	
158. Falkovsky	32, 957		
159. Bodzekhovsky	35, 000	30	
160. Radostovsky	760		
161. Przisoukshy	83, 200	15, 500	
162. Bialachevsky	13, 122		
163. Malenetzy	33, 322	13, 560	
164. Makhorakshy	2, 000		
165. Rzouzovsky	28, 240		
166. Blijinsky	5, 069		
167. Khlevisky	144, 774	2, 366	
168. Neklansky	7, 381		
169. Borkovitzki	2, 350		
170. Konsky	10, 570		
171. Fidor	6, 250		
172. Krasnensky	52, 820		
173. Tchezinsky	5, 405	1, 552	
174. Rouchenitzky	3, 000		
175. Vinek	16, 000		
176. Miatchef	2, 500		
177. Chronztovsky	5, 014		
178. Klutchevsky	7, 000		
179. Drzevitzky	1, 762		
180. Sloupia	5, 000		
181. Dankof	1, 300		
182. Berezovsky	3, 130		
183. Humer	8, 000		
184. Irena	136, 000		
185. Masanovsky	30, 000		
186. Smougy	5, 750		
187. Jusèfin	5, 700		
188. Lassky	10, 550		
189. Selnitza	950		

Production of iron, and of steel—Continued.

Works.	Iron in bars and rods.	Sheet-iron of all kinds.	Steel, cast and hammered.
I.—*Private works, kingdom of Poland*—Continued.	*Pouds.*	*Pouds.*	*Pouds.*
190. Konezpol	1, 586	12, 120	....
191. Rembelidzé	6, 010	....	....
Total	890, 524	48, 278	....
J.—*Private works, Finland.*			
192. Matildadal	39, 232	....	....
193. Dalsbrouk	94, 409	....	....
194. Hegfors	14, 563	....	....
195. Fiskars	87, 464	....	....
196. Stremsdal	39, 187	....	....
197. Vertsilé	109, 849	....	....
198. Ekaterinensky	73, 288	1, 560	64, 625
199. Fridérixfors	17, 035	....	....
200. Kiriakkala	14, 551	....	....
201. Jokkis	7, 177	....	....
202. Viérou	8, 533	....	....
203. Kimé	12, 756	....	....
204. Orisberg	9, 407	....	....
205. Bilnès	13, 078	....	....
206. Faghervik	10, 951	....	....
207. Mariéfors	14, 705	....	....
208. Svertó	20, 466	....	....
209. Kantoua	7, 023	....	....
210. Stremfors	10, 439	....	....
211. Norrmark	6, 767	....	....
212. Nésé	1, 132	....	....
213. Irkekoski	7, 273	....	....
214. Varkaous	3, 544	....	....
215. Oravi	733	....	....
216. In Catalan forges	34, 727	....	....
Total	658, 289	1, 560	64, 625
Grand total	11, 959, 622	2, 998, 975	442, 241
Grand total of bar, rod, and sheet iron	14, 958, 597		

There is a large consumption of iron and copper in the manufactures of Russia, notably in the manufacture of artillery-arms, machinery, and iron vessels, but the statistics of these manufactures are acknowledged to be very imperfect, inasmuch as some one hundred and fifty establishments for working iron do not report to the government mining department. And the working of iron to a great extent is not confined wholly to large establishments; there are entire districts where the peasants are exclusively occupied in working iron during the winter. For these reasons the following figures represent only a small part of the extent of metal-work in Russia in the year 1871:

	Pouds.
Steel cannon	15, 682
Apparatus	20, 493
	46, 175
Cast-iron cannon	51, 485
Munitions of artillery	405, 831
Iron boats	7, 868

Cast-iron work:	Pouds.
In cupolas	1,306,110
In reverberatory furnaces	584,169
	1,890,279
Locomotives	3,596
Iron-work	850,831
Copper and steel work	36,813
	Pieces.
Copper and steel work	287,440
Side-arms	40,708
Arm-apparatus	30,326
Scythes	33,750

51. PRODUCTION OF COAL IN RUSSIA.—The production and distribution of mineral coal, petroleum, and salt in Russia are shown by the annexed tabular list of collieries, &c., which lists are important in connection with the foregoing lists of iron-works:

Collieries in Russia.

Name and location.	Coal.	Anthracite.	Bituminous, shale, and lignite.
A.—*Moscow coal-basin.*	*Pouds.*	*Pouds.*	*Pouds.*
1. Malëvsky	1,316,839		
2. Tovarkovsky	760,560		
3. Novoselebny	1,300,000		
4. Jacenetsky	200,000		
5. Slaviansky	5,000		
6. Zelenensky	150,000		
7. Mouraevinsky	1,145,000		
8. Tchoulkovsky	2,000,000		
9. Paveletzky	1,800,000		
Total	8,677,399		
B.—*Elisabetgrad basin.*			
10. Ekatérinopolsky			300,000
11. Djourovsky			700,000
Total			1,000,000
C.—*Donetz coal-basin.*			
(*a*) Territory of the Cossacks of the Don.			
12. Grouchevsky		10,603,467	
13. Bolche-Nesvitaïsky		35,757	
14. Vlassovsky 15. Ryghinsky 16. Bambétof 17. Bérestovsky		478,371	
18. Territories of Tcherkask, Donetz, and of the Don		876,239	
19. Private collieries. Arrondissement de Miouss		2,115,621	
(*b*) In the government of Ekaterinoslaf.			
MINES OF THE CROWN.			
20. Licitchansky	500,761		
PRIVATE MINES.			
First district.			
21. Nikitovsky, (M. Poliakoff)	265,000		
22. Volyntzevsky	7,217		
23. Alexandrovsky	530,181		

Collieries in Russia—Continued.

Name and location.	Coal.	Anthracite.	Bituminous, shale, and lignite.
Private mines, first district—Continued.	*Pouds.*	*Pouds.*	*Pouds.*
24. Sociét. de la Nouvelle Russie	1, 176, 318		
25. J. Routchenko	76, 000		
26. A. Routchenko	200, 000		
27. W. Routchenko	200, 000		
28. Courakhovsky	100, 000		
29. Karakovsky	100, 000		
30. Guirgensonovsky	100, 000		
31. Tcherbinovsky	42, 000		
32. Nikitovsky, (M. Zaitzeff)	20, 000		
33. Gelezniansky	10, 000		
34. Roubejansky, (M. Bogdanovitch)	50, 000		
35. Roubejansky, (M. Chakhoff)	180, 000		
Second district.			
36. Tochkovsky	30, 000		
37. Petromarievsky, (M. Vincler)	56, 000		
38. Petromarievsky, (des paysans)	20, 000		
39. Sokolovsky, (M. Sokoloff)	255, 000		
40. Sokolovsky, (des paysans)	70, 000		
41. Goloubovsky	1, 282, 250		
42. Dvienadzatirotsky	50, 000		
43. Odinadzatirortsky	85, 000		
44. Sofievsky	5, 000		
45. Jourievsky, (M. Goloub)	25, 000		
46. Jourievsky, (des paysans)	50, 000		
47. Beliansky	200, 000		
48. Bogoroditzky	100, 000		
49. Kozlovsky, (M. Kozloff)	60, 000		
50. Kozlovsky, (des paysans)	30, 000		
51. Boulatzelevsky	200, 000		
52. Jonovsky	80, 000		
53. Glafirovsky	30, 000		
54. Bougaevsky	25, 000		
55. Lazorefsky, (M. Souvoroff)	3, 000		
56. Lazorefsky, (des paysans)	40, 000		
57. Malonikolaevsky		10, 000	
58. Petropavlovsky		8, 000	
59. Christoforovsky		5, 000	
60. Chroustalny		10, 000	
61. Krasnokoutsky		10, 000	
62. Popovsky		5, 000	
63. Fachtchevsky		8, 000	
64. Gorodichtchensky		25, 000	
Total	6, 270, 727	14, 190, 455	
D.—*Ural coal-basin.*			
65. Kysélovsky	428, 410		
66. Kysélovsky, (Vsevolojsky)	30, 075		
67. Alexandrovsky	373, 920		
Total	832, 405		
E.—*Kingdom of Poland.*			
(*a*) Mines of the crown.			
68. Xavéry	2, 584, 966		
69. Tsechkovsky	1, 252, 940		
70. Labentsky	352, 495		
71. Novaia	1, 506, 862		
72. Reden	108, 486		
Total	5, 805, 749		
(*b*) Private mines.			
73. St. Barbe	607, 207		
74. Victor	3, 338, 272		
75. Ignace	1, 460, 103		
76. George	2, 727, 476		
77. André	2, 058, 500		
78. Jeanne			360, 000
79. Miachevska			42, 000
80. Sigismund	209, 315		
81. Vincente	51, 125		
82. Edouard	1, 750, 548		
Total	12, 202, 546		402, 000

Collieries in Russia—Continued.

Name and location.	Coal.	Anthracite.	Bituminous, shale, and lignite.
F.—*Basin of Kouznetzk, government of Tomsk.*	*Pouds.*	*Pouds.*	*Pouds.*
83. Batchatsky	228, 000	....	....
G.—*Territory of the Kirghises of Siberia.*			
84. Karagandinsky	404, 521	....	....
85. Kysyltavsky	41, 529	....	....
86. Doungoulek-Sor	35, 386	....	....
Total	481, 436	....	....
H.—*Eastern Siberia.*			
87. Douïsky	295, 894	....	....
I.—*Caucasus.*			
88. Koubansky	140, 000	....	....
89. Karadaksky	....	....	52, 941
Total	140, 000	....	52, 941
J.—*Turkistan.*			
90. Tatarinovsky (1870)	75, 000	....	....
Grand total	35, 009, 156	14, 190, 455	1, 454, 941
Grand total of production		50, 654, 552	

Production of petroleum.

Sources.	Number of wells.	Quantity.
A.—*Territory of Terek.*		*Pouds.*
1. Grosnensky, Mamakaïevsky, Karaboulaksky	74	22, 647
2. Bragounovsky	90	6, 750
3. Bénoïevsky	8	405
Total	172	29, 802
B.—*Territory of Dagestan.*		
4. Bérìksky et Dgémikentsky	20	2, 700
5. Naft-Koutansky	37	1, 013
6. Bachlinsky	42	4, 264
7. Toupsous-Koutansky	17	1, 978
8. Ghik-Salgane-Koutansky	3	1, 350
9. Nap-Koutansky	8	1, 485
Total	127	12, 790
C.—*Territory of Kouban.*		
10. Khadygensky	4	675
11. Koudako	10	97, 449
Total	14	98, 124
D.—*Government of Tiflis.*		
12. Mirsansky, Chiraksky and Eldarsky	99	69, 522
E.—*Government of Bakou.*		
13. Bakinsky, Derbentsky and Kaïtago-Tabassaransky	285	1, 165, 285
Grand total	697	1, 375, 523

Production of chrome-iron ore.

Sources.	Number of mines.	Pouds.
Private mines in the Ural.		
1. Verkh-Icetsky	2	237, 685
2. Kychtimsky	1	54, 897
3. Chaïtansky	1	109, 264
4. Oufaleïsky	2	49, 127
Total	6	450, 973

Production of salt.

Sources.	Pouds.
A.—*Rock-salt.*	
MINES.	
1. Iletsk°ïa Zachtchita	1, 048, 567
2. Mont Tchiptchatchi	802, 638
3. Koulpinsky	1, 012, 212
4. Nakhitchévansky	203, 625
Total	3, 067, 042
B.—*Salt obtained by evaporation.*	
WORKS.	
5. Dédioukhinsky	2, 477, 743
6. Lenvensky	3, 699, 373
7. Oussolsky	3 390, 690
8. Solikamsky	935, 605
9. Ledengsky	170, 264
10. Totemsky	6, 865
11. Sérégovsky	233, 532
12. Nénoksky	69, 965
13. Kouloisky	429
14. Ounsky	8, 173
15. Loudsky	3, 836
16. Small works on the borders of the White Sea	5, 569
17. Balakhninsky	26, 828
18. Slaviansky	151, 624
19. Troïtsky	100, 801
20. Oustekoutsky	42, 744
21. Irkoutsky	330, 555
Total	11, 654, 596
C.—*Salt from salt lakes.*	
SALT LAKES.	
22. Elton	370, 000
23. D'Astrakhan	4, 379, 086
24. Gaidoukssky	235, 618
25. Mojarsky	497, 763
26. De Crimée	6, 257, 015
27. Kouyalnitsky	715, 287
28. Tchalghinsky	201, 095
29. Du Transcaucase	345, 265
30. Manytchsky des Cosaques du Don, (1870)	124, 680
31. Des Cosaques du Kouban, (1870)	82, 776
32. Indersky des Cosaques de l'Oural, (1870)	192, 200
33. Borovya et Aléouskya	30, 426
34. Borsinsky	90, 581
35. Jakoutsky	11, 100
Total	13, 532, 892
Grand total	28, 254, 530

In the concluding tables a general view is presented of the total production of the mines and metallurgical works of the Russian Empire in the years 1870 and 1871.

General table of the production of the mines and metallurgical works of Russia, 1870 and 1871.

	1871.	1870.
Washings.	*Pouds.*	*Pouds.*
Auriferous sand	1, 081, 518, 424	983, 475, 095
Platiniferous sand	10, 440, 650	9, 609, 150
Extracted by washing.	*Poud. liv. zol. gr.*	*Poud. liv. zol. gr.*
Washed gold	2, 399 38 2 8	2, 156 23 16 19
Crude platinum	125 6 56 0	118 38 33 0
Extracted from mines.	*Pouds.*	*Pouds.*
Argentiferous lead-ore	2, 177, 540	2, 116, 404
Copper-ore	6, 222, 759	6, 392, 622
Iron-ore	50, 823, 668	48, 763, 156
Zinc-ore	2, 629, 477	2, 666, 754
Tin-ore	22, 909	66, 292
Cobalt-ore	649	1, 249
For vitriol, (pyrites excepted)	50, 000	95, 000
Coal	50, 654, 552	43, 230, 589
Graphite	....	....
Petroleum	1, 375, 523	1, 704, 455
Chromic iron	450, 973	600, 024
Salt	28, 254, 530	29, 013, 458
Smelted.		
Argentiferous lead-ore	1, 892, 636	2, 066, 792
Copper-ore	6, 384, 154	7, 190, 213
Iron-ore	48, 567, 152	48, 464, 114
Zinc-ore	1, 665, 495	2, 117, 318
Tin-ore	?	?
Products obtained.	*Poud. liv. zol.*	*Poud. liv. zol.*
Silver from the ores	828 30 27	867 30 68
Lead	107, 963 26 0	100, 653 20 0
Copper	260, 006 31 0	308, 440 0 0
Tin	475 0 0	1. 032 0 9
	Pouds.	*Pouds.*
Pig-iron	18, 854, 634	18, 557, 412
Cast iron in different forms	3, 149, 884	3, 401, 914
Total of cast iron	22, 004, 518	21, 959, 326
Zinc, crude	166, 581	221, 328
Cast iron from cupolas	1, 306, 110	1, 343, 891
Cast iron from reverberatory furnaces	452, 239	620, 851
Total of cast iron	1, 890, 279	1, 964, 742
Iron in bars, rods, rails, &c	11, 959, 622	11, 971, 459
Iron in sheets	2, 998, 975	3, 246, 449
Total of iron	14, 958, 597	15, 217. 908
Steel	442, 241	536, 086
Copper, in sheets	21, 277	29, 642
Zinc, in sheets	30, 000	26, 844
Cobalt matte	....	305½
Iron-work	850, 831	958, 634
Work in other metals	36, 813	53, 885
Vitriol, &c	4, 605	9, 910
	Roubles.	*Roubles.*
Total of different mints	11, 254, 744	33, 545, 643
Now working.	*Number.*	*Number.*
Gold-mines	979	1, 208
Platina-mines	6	6
Argentiferous lead	21	26
Mines of copper	76	71
Mines of iron	1, 174	1, 283
Mines of zinc	6	6
Mines of cobalt	1	1
Mines of tin	1	1
Mines of coal	327	193
Mines of graphite	....	....
Mines of pyrites	1	2
Mines of chromic iron	6	9
Mines of rock-salt	4	4
Sources of petroleum	697	7 7

General table of the production of the mines and metallurgical works of Russia, 1870 *and* 1871—Continued.

	1871.	1870.
	Number.	*Number.*
Mints	2	2
Refineries for gold	2	2
Silver-works	9	10
Copper-works	35	39
Cast-iron works	153	164
Zinc-works	5	4
Cobalt-works	....	1
Tin-works	1	1
Works producing iron and steel	214	214
High-furnaces	222	245
Puddling-furnaces	431	445
Refinery-furnaces	667	692
Forges	818	924
Steel-furnaces	372	495
Cupola-furnaces	150	161
Reverberatory-furnaces	93	93
Copper-furnaces	247	262
Silver-furnaces	130	130
Zinc-furnaces	141	128
Steam-engines	515	482
Power of engines	14, 477	13, 730
Water-motors	2, 224	2, 223
Power of motors	39, 938	51, 269
Number of workmen employed in the mines and works	158, 446	156, 197
Number of workmen employed in the gold-washings	67, 854	69, 186
Number of workmen employed in the salines, (approximated)	40, 000	40, 000
Total of workmen employed	266, 300	263, 383

CHAPTER VII.

GREAT BRITAIN.

PRINCIPAL EXHIBITORS; CAMMELL & CO.; JOHN BROWN & CO.; BOWLING IRON COMPANY; THOMAS FIRTH & SON'S STEEL INGOTS; LANDORE SIEMENS STEEL COMPANY; WHITWELL'S HOT-BLAST STOVES; SIEMENS'S DIRECT PROCESS; DECORATED TIN-PLATE.

152. The exhibition of iron and steel by Great Britain is meager compared with its rank as first on the list of iron-producing countries. There are but few exhibitors, and no effort appears to have been made to present a general or statistical view of the extent and value of British iron-industry, as was done at the Paris Exposition in 1867.

153. The annexed tables exhibit the exports of iron and steel from Great Britain for the years 1873 and 1874, and during the first half of the year 1875. These figures are compiled and published by the Board of Trade authorities, and are cited by Mr. Forbes in the report of the Iron and Steel Institute of Great Britain.

Exports of iron from Great Britain in the years 1873, 1874, *and the first half of* 1875.

Whither exported.	1873.	1874.	1875.
Pig:	*Tons.*	*Tons.*	*Tons.*
To Germany	146, 743	61, 820	106, 911
To Holland	189, 868	84, 546	95, 771
To Belgium	81, 317	40, 578	58, 074
To France	52, 353	26, 983	42, 184
To United States	63, 183	26, 760	26, 580
To British North America	18, 847	14, 958	22, 502
To other countries	82, 434	64, 253	80, 577
Total	634, 745	319, 898	432, 599
Bar, angle, bolt, and rod:			
To Russia	6, 533	6, 031	7, 395
To Germany	19, 203	3, 697	3, 618
To Holland	8, 303	2, 765	3, 689
To France	2, 142	369	286
To Italy	8, 395	8, 871	10, 551
To Turkey	3, 240	5, 853	5, 150
To United States	20, 535	3, 193	1, 380
To British North America	19, 205	12, 771	10, 143
To British India	7, 892	18, 224	25, 082
To Australia	7, 624	9, 003	15, 678
To other countries	47, 153	44, 708	45, 416
Total	150, 225	115, 485	128, 388
Railroad, of all sorts:			
To Russia	47, 780	74, 460	30, 927
To Sweden and Norway	15, 876	39, 968	25, 293
To Denmark	2, 808	5, 897	2, 063
To Germany	24, 375	3, 297	737
To Holland	8, 214	9, 004	3, 388
To Belgium	16, 843	12, 306	423
To France	2, 139	1, 613	51
To Spain and Canaries	6, 548	10, 985	6, 168
To Italy	13, 084	10, 254	5, 338
To Turkey	552	8, 889	28
To Egypt	1, 667	10, 930	1, 474
To United States	120, 468	64, 969	15, 734

Exports of iron from Great Britain, &c.—Continued.

Whither exported.	1875.	1874.	1873.
	Tons.	*Tons.*	*Tons.*
To Brazil	3, 963	11, 597	5, 059
To Peru	5, 467	4, 628	11, 455
To Chili	2, 908	9, 185	11, 045
To British North America	29, 774	28, 710	52, 790
To British India	8, 132	25, 026	16, 901
To Australia	9, 993	38, 088	42, 015
To other countries	27, 839	57, 461	28, 418
Total	348, 439	427, 267	259, 307
Wire of iron or steel, (except telegraph-wire,) galvanized or not	15, 992	14, 714	21, 960
Hoops, sheets, boiler and armor plates:			
To Russia	8, 520	3, 312	5, 247
To Germany	17, 213	2, 888	5, 850
To Holland	6, 282	3, 076	4, 827
To France	3, 375	714	803
To Spain and Canaries	2, 430	3, 481	2, 843
To Italy	4, 676	3, 638	4, 465
To United States	12, 935	2, 892	3, 313
To British North America	5, 742	3, 342	3, 168
To British India	6, 279	8, 857	16, 542
To Australia	10, 410	10, 605	17, 527
To other countries	30, 580	26, 004	30, 016
Total	108, 442	68, 809	94, 601
Tin plates:			
To France	2, 095	1, 236	1, 099
To United States	49, 645	49, 717	52, 323
To British North America	1, 619	952	1, 878
To Australia	2, 231	1, 839	1, 398
To other countries	11, 253	9, 790	15, 432
Total	66, 843	63, 534	72, 130
Cast or wrought, and all other manufactures (except ordnance) unenumerated:			
To Russia	21, 846	7, 405	8, 060
To Germany	18, 251	6, 245	8, 950
To Holland	8, 710	4, 120	4, 629
To France	2, 601	1, 813	2, 353
To Spain and Canaries	5, 098	5, 452	3, 326
To United States	7, 136	12, 008	4, 703
To Peru	4, 427	1, 463	758
To Brazil	6, 857	4, 268	3, 962
To British North America	8, 135	13, 031	8, 098
To British Possessions in South Africa	2, 604	2, 869	3, 065
To British India	9, 533	10, 462	14, 018
To Australia	14, 528	16, 708	21, 695
To other countries	30, 938	43, 808	34, 634
Total	140, 664	129, 652	118, 251
Steel, unwrought:			
To France	1, 478	1, 284	1, 355
To United States	10, 879	6, 520	5, 566
To other countries	8, 295	6, 443	7, 929
Total	20, 652	14, 247	14, 850
Old iron for remanufacture:			
To United States	26, 650	3, 586	3, 783
To other countries	14, 705	10, 967	5, 062
Total	41, 355	14, 553	8, 845
Manufactures of steel, or steel and iron combined	5, 314	4, 561	5, 249
Total of iron and steel	1, 532, 662	1, 172, 720	1, 156, 180

154. PRINCIPAL EXHIBITORS.—The heaviest exhibition in the British section is made by the firm of Cammell & Co., of Sheffield, which sends cast-steel propeller-blades, rails, wheels, axles, and armor-plates. The firm of John Brown & Co., which sent such massive iron plates to the

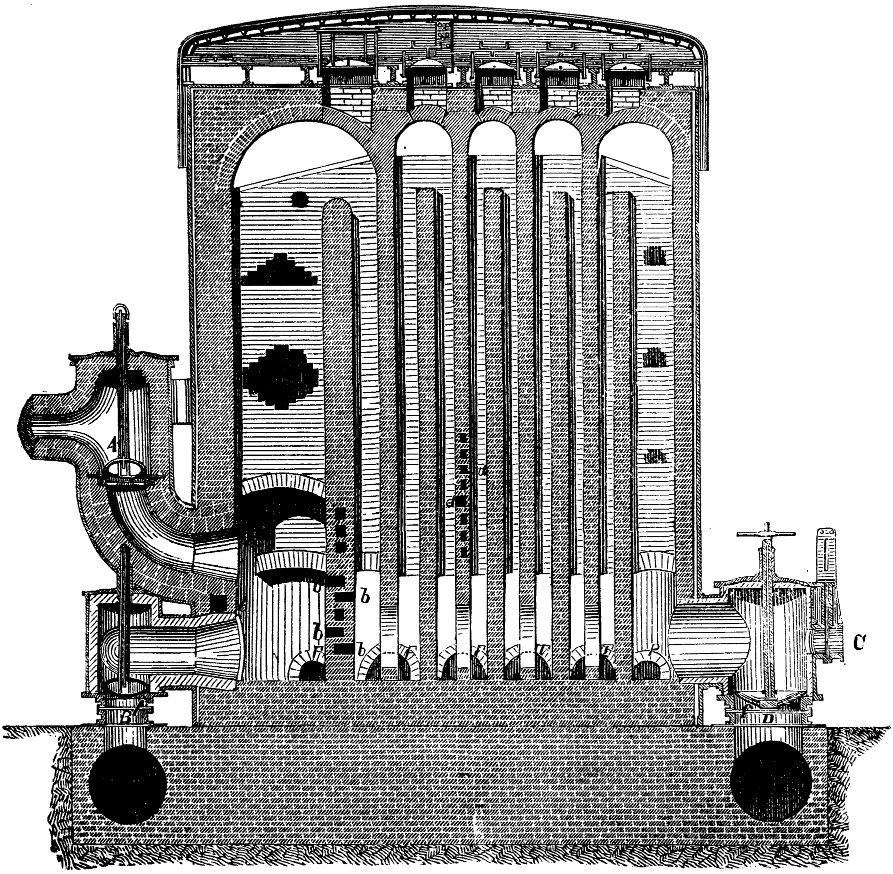


FIG. 61.—Whitwell's hot-blast stove, vertical section.

Paris Exposition in 1867, is content this year with making a very full display of railway-material, and two small armor-plates showing the effects of round shot and of pointed shot. The large plate sent by Cammell & Co. is 20 feet long by 7 feet wide and 10 inches thick, and is intended for the German turret-ship Borussia.

The Bowling Iron Company exhibits iron and steel boiler-plates, steel castings, and railway-material. Steel tires for railway-wheels are shown bent while cold into various forms without breaking. Thomas Firth & Son exhibit steel ingots; a homogeneous steel core for a 35-ton gun, and forgings of the same metal for artillery and rifle barrels. The Landore Siemens Steel Company send samples of their steel rail and tires, and of the steel barrels for the Martini-Henry rifle. In the exhibition made by Johnson & Nephew, Manchester, there is a weldless wire 1,770 yards long.

There are several other contributions of considerable interest, but the most important in a metallurgical point of view are the exhibitions made by Thomas Whitwell of his hot-blast stoves, and by C. William Siemens of a new process for the production of iron or steel.

155. WHITWELL'S HOT-BLAST STOVES.—The patent fire-brick stoves of Mr. Whitwell are intended to heat the blast of iron-furnaces. The invention is represented by a very perfect model, accompanied by a full series of drawings, and, what is better, by an intelligent agent to explain them. The stoves are designed to replace the ordinary iron pipes used for heating the blast, substituting for them a series of fire-brick chambers and passages which are heated by the direct contact of the flames of the burning gases taken from the furnace in the usual way. When the mass of brick is sufficiently heated the gas is shut off and the blast is admitted. This in passing through the same heated chambers acquires the temperature of the bricks. The brick-work, of course, gradually cools down, but by the time the last chamber begins to be too cool another stove has been heated up, and the blast is made to pass through that. The stoves are thus alternately heated by the burning gas and cooled by the blast. The advantages of this system are numerous. One of the greatest is uniformity of temperature of blast, which cannot be counted upon with iron pipes. The bricks are a great store-house of heat, and cool gradually. Iron pipes cool suddenly when from any cause the supply of burning gas is stopped. The air being brought into direct contact with the surfaces previously heated by the gas, absorbs the heat quickly and with little loss. The apparatus is simple, is easily erected, and is being extensively introduced. For cupola-furnaces, making 600 tons a week, two stoves, 12 feet square by 21 feet high, and with 2,270 superficial square feet of heating-surface in each, are necessary.

The construction of these stoves is shown by the annexed figures, giving vertical and horizontal sections and plans.

FIG. 61.—*Heating the stove—vertical section.*—The hot-blast valve A and the cold-blast valve C being closed, the gas-valve B is opened, through

which the gas enters the stove, traverses up and down the spaces between the upright walls, and enters the chimney-flue by the valve D. Heated air is supplied to the gas by means of the air-valves *a* and *c* and passages *b* and *d*, by which a most intense combustion is gained. The internal heat of the stove, as well as the combustion of the gas, is observed by the eye-pieces *e e*.

FIGS. 61, 62.—*Heating the blast.*—The chimney-valve D and gas-valve B being closed, and the hot-blast valve A being opened, the cold blast is admitted through the cold-blast valve C and issues from the stove by the valve A *red hot*, all other valves being closed perfectly tight.

FIGS. 61, 63, 64.—*Cleaning the stove.*—When it is required to clean a stove the top cleaning-doors E are opened and the walls scraped with the "cleaning-tools," when the dust deposited on the heating-surfaces falls to the bottom of the stove, and is removed by the bottom cleaning-doors F.

The upper plan, page 230, shows the arrangement of the stoves to four furnaces *in full blast* at the Consett Iron-Works; but this plan may be varied to suit all circumstances.

The following distinguishing advantages are claimed by the inventor for these stoves:

1st. That they will stand a temperature of 2,000° without damage.

2d. There is no wear and tear of cast-iron pipes or material.

3d. They are sooner cleaned than any others, the time required between aying off and starting again being six hours. They are not cooled down, but are cleaned from the outside while red-hot. This takes place at intervals at from three to six months, according to the amount of dust in the gas.

4th. The principle on which the stoves are constructed insures the greatest economy of gas or fuel, whilst the heat that is obtained in the blast is nearly the whole of that given off by such gas or fuel.

5th. The cost of the stoves is not proportionately more per furnace than that of ordinary cast-iron plant, equal to modern requirements.

6th. These fire-brick stoves effect a saving of several cwts. of fuel per ton of iron made.

7th. The stoves being riveted and calked air-tight, there is no loss by bad joints, and hence a large amount of wear and tear is saved to the blowing engines.

8th. The areas throughout are so regulated that there is *no loss* of pressure by friction, but a pressure of four pounds in the engine-house gives *an equal pressure at the tuyere*, where the plans of the patentee are properly carried out.

9th. The immense reservoir of caloric stored up in these stoves, each red-hot wall acting as a fly-wheel so to speak, and giving out its power when most required, produces the best effect on the working of a furnace.

10th. These stoves form *a perfect regulator* to the blast, acting in this

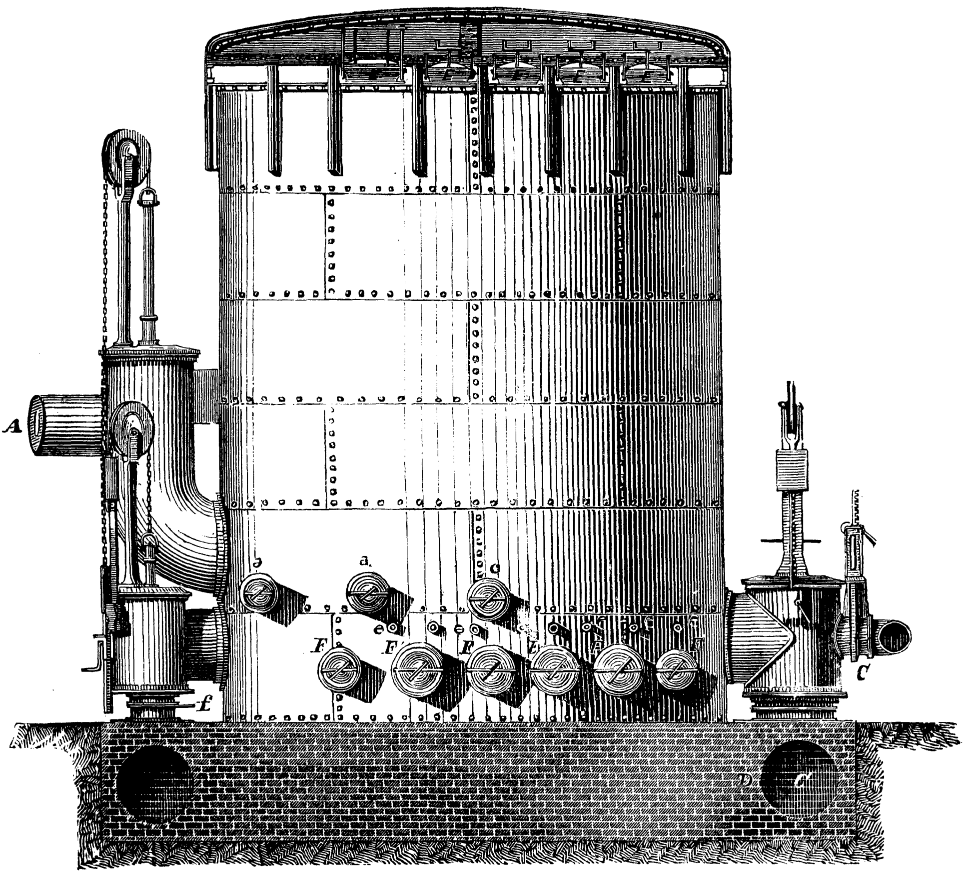


FIG. 62.—Whitwell's hot-blast stove, elevation.

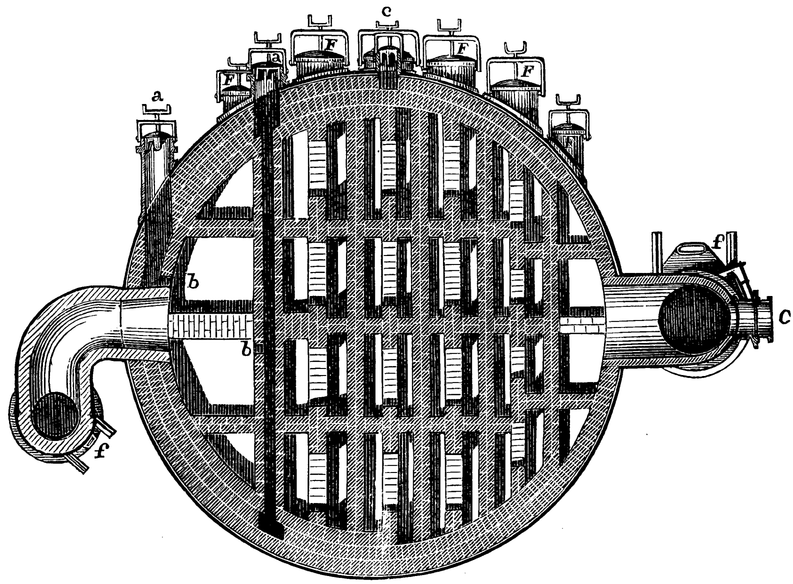


FIG. 63.—Whitwell's hot-blast stove, horizontal section.

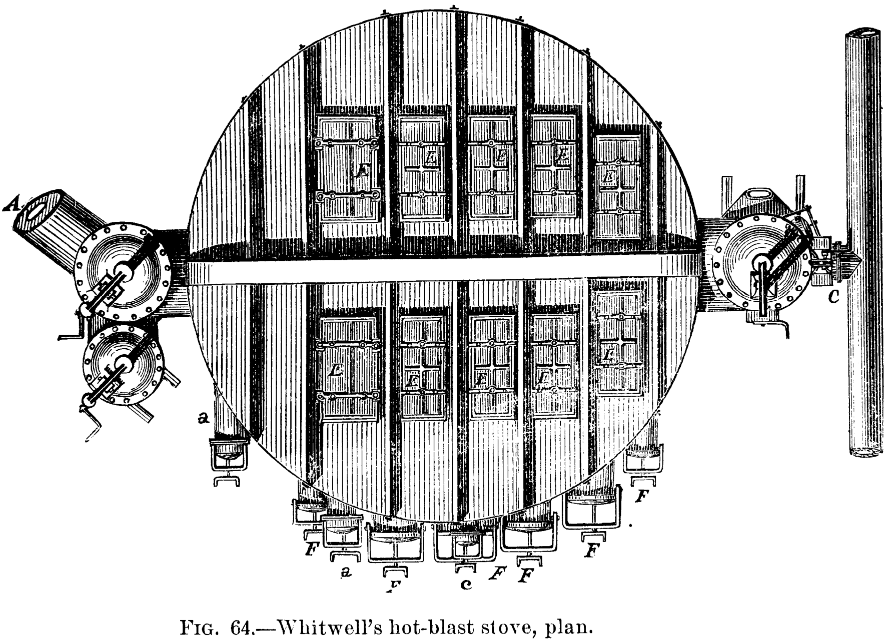


FIG. 64.—Whitwell's hot-blast stove, plan.

respect as the air-vessel in a force-pump, and dispensing altogether with the large air-regulators that are found necessary in many works, the blast being perfectly steady at the tuyere.

The use of hot blast, of the temperature obtainable from these fire-brick stoves, enables iron-masters to effect a saving in fuel, much beyond what can be obtained by any amount of cast metal pipes; and, if a heat from 1,500 to 2,000 degrees and upwards be desired, these stoves stand it without damage, whilst metal ones at once give way.

It is now generally known that *high* furnaces do not work well with many kinds of fuel and ores, where those of *moderate* dimensions have no difficulty, but the hot blast produced by Whitwell's fire-brick stoves never fails to effect the desired saving in fuel, whilst at the same time proving a corrective to nearly all those evils that lower the make and quality of pig-iron. In France, Alsace, Lorraine, the hematite districts, &c., high furnaces have been already tried, but have failed chiefly on account of their scaffolding; the approved height of furnace is now from 55 to 60 feet, except in Cleveland, whether for smelting hematite, magnetic, oolitic, or carbonaceous ores.

The original patents of Messrs. Siemens & Cowper have now expired, and therefore the extra royalties hitherto imposed are saved. Patents have been granted to these stoves in Great Britain, France, Belgium, the United States, Luxembourg, Russia, Austria, Spain, Portugal, Sweden, Norway, Italy, the East Indies, New Zealand, and Canada.

The celebrated firm of Messrs. *Schneider & Cie*, Le Creusot, France, have during the past year blown in their first furnace on this system. They make, with four stoves, 400 tons per week of Bessemer pig. *The Dowlais Iron Co.*, Merthyr Tydvil, have also adopted the stoves for the same purpose, not only on account of the heat of the blast, but the *perfect regularity* with which they work.

In general terms one stove will make 100 tons of pig per week; at the *Consett Works*, one stove makes above 125 tons *gray iron per week;* and for some time past, the furnaces on a mixture with 46 per cent. metallic iron have made, with four stoves, 500 tons per week; the average temperature of the blast is 1,400° by Siemens' pyrometer.

In Luxembourg, with oolitic ores of 32 per cent. metallic iron, and coke with 18 per cent. of ash, the consumption is 20 cwt. coke per ton of gray pig; production 525 tons per week per furnace.

At Weilerbach, in a charcoal furnace 29 feet high, with oolitic ores of 32 per cent. metallic iron, the consumption is 20 cwt. charcoal per ton of gray pig; the adoption of fire-brick stoves in this case to an old furnace enabled the proprietors to use a mineral of *less value* producing the *same quality of pig as was formerly made with more expensive ores;* the economy in fuel attained by the fire-brick stoves is 6 cwt. charcoal per ton of pig, and castings of the finest description are run direct from the blast furnace, the iron being now exceedingly soft.

Heating surface.—In these stoves *every square inch* is effective as heat-

ing surface, as *the burning gases* are compelled between entering and leaving the stove to traverse the *whole surface of the bricks exposed;* the blast in its turn also passes over the identical surfaces previously heated by the gas, and absorbs from them the heat required.

In no other stoves where brick-work is used as heating-surface is this the case; hence in Whitwell's fire-brick stoves a *much smaller quantity* of heating-surface is necessary for heating the blast, inasmuch as every part of it is effective.

At this date, the stoves are adopted by 33 firms, including some of the largest in Europe, *Consett*, *Dowlais*, *Le Creusot*, *De Wendel & Cie.*, *Krupp*, *Bochum*, *Dupont & Dreyfuss*, *&c.*

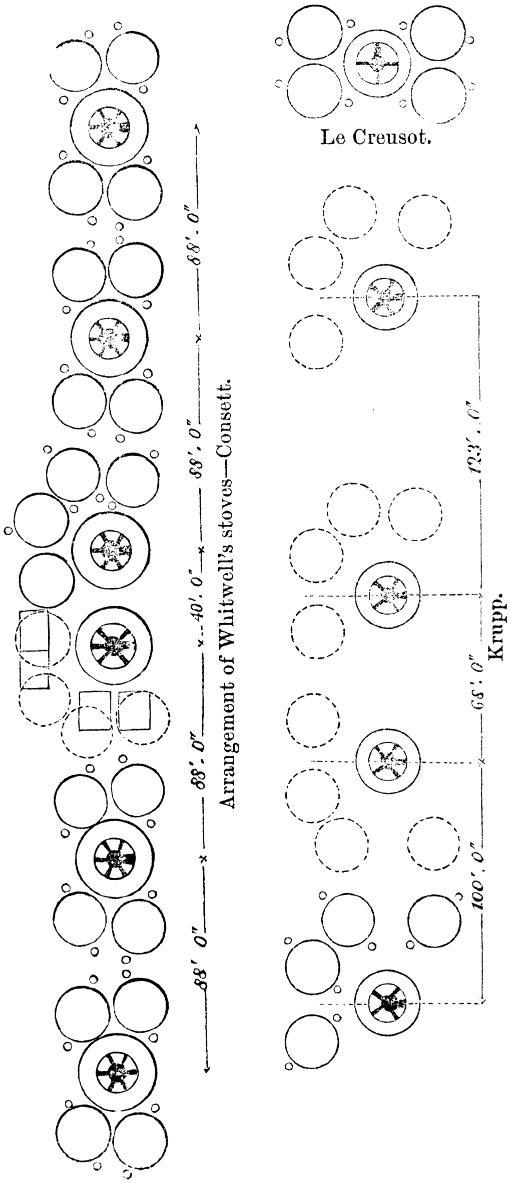
These hot-blast fire-brick stoves have been adopted by the following firms:

	Stoves.		
	Furnaces.	Stoves building.	Stoves in blast.
GREAT BRITAIN.			
Consett Iron Company, limited, Durham	5	4	16
North of England Industrial Iron Company, limited, Carlton Iron Works, Stockton-on-Tees.	3	0	12
The Solway Hematite Iron Company, limited, Maryport. (Bessemer pig)	2	......	8
The Moss Bay Hematite Iron Company, Workington. (Bessemer pig)	3	8	4
The West Cumberland Hematite Iron Company, Workington	1	4	......
The Butterley Iron Company, Alfreton, Derby	1	2	......
The Tees Bridge Iron Company, limited, Stockton-on-Tees	2	0	8
Wm. Whitwell & Co., Thornaby Iron Works, Stockton-on-Tees	2	10	......
Bell Brothers, Walker Iron Works, Newcastle-on-Tyne	2	8	......
SOUTH WALES.			
The Dowlais Iron Company, Merthyr Tydvil	1	4	......
The Governor and Company of Copper Miners in England, Cwm Avon, Port Talbot	1	4	......
CONTINENT.			
FRANCE.			
M. M. Schneider & Cie., Le Creusot. (Bessemer pig)	1	......	4
Le Baron Adelsward, Longwy	1	4	......
Société de Vezin Aulnoye, Nancy	1	4	......
Société Anomyme des Forges de Denain	1	4	......
Société de Commentry et Chatillon	1	4	......
PRUSSIA.			
F. Krupp, Johanneshutte, Duisberg	1	4	......
Friederich-Wilhelms-Hütte, Mulherm, a. d. Ruhr	2	8	......
Société D'Acier Bochum, Westphalia	2	8	......
Société de Horde, Dortmund	1	4	......
J. H. Dressler, sen., Siegen	1	4	......
Scha'ker, Gruben & Hütten Verein, Gelsen-Korchen	2	8	......
Concordiahütte Eschweiler	1	4	......
ALSACE LORRAINE.			
M. M. Le Petit Fils de Fois, De Wendel & Cie., Hayange	2	8	......
M. M. Dupont & Dreyfuss, Ars-sur-Moselle	1	4	......
GRAND DUCHY OF LUXEMBOURG.			
Société Anonyme Des Hauts-Fourneaux, Esch-sur-L'Alzette	2	4	4
M. M. Philip & Bernard Serrais, Weilerbach. (Charcoal pig)	1	......	2
M. M. Metz & Cie., Forges d'Eich	1	2	......

	Furnaces.	Stoves building.	Stoves in blast.
BELGIUM.			
Société Anonyme des Hauts Fourneaux, Athus	2	10	......
Société John Cockerill, Seraing, Liege	2	8	......
SPAIN.			
Cantabrian Iron Company, limited, Bilboa	2	6	......
UNITED STATES.			
Cedar Point Iron Company, Port Henry, New York	1	4	......
Boyle, Ditmans & Jarais, Rising Fawn, Georgia	1	3	......
Total	53	149	58

Total: 33 companies, 53 blast-furnaces, 207 stoves.

The arrangement of the stoves at Consett, at Krupp's, and at Creusot is shown in the annexed cut.


Le Creusot.
88′ 0″
88′ 0″
40′ 0″
88′ 0″
88′ 0″
Arrangement of Whitwell's stoves—Consett.
123′ 0″
68′ 0″
100′ 0″
Krupp.

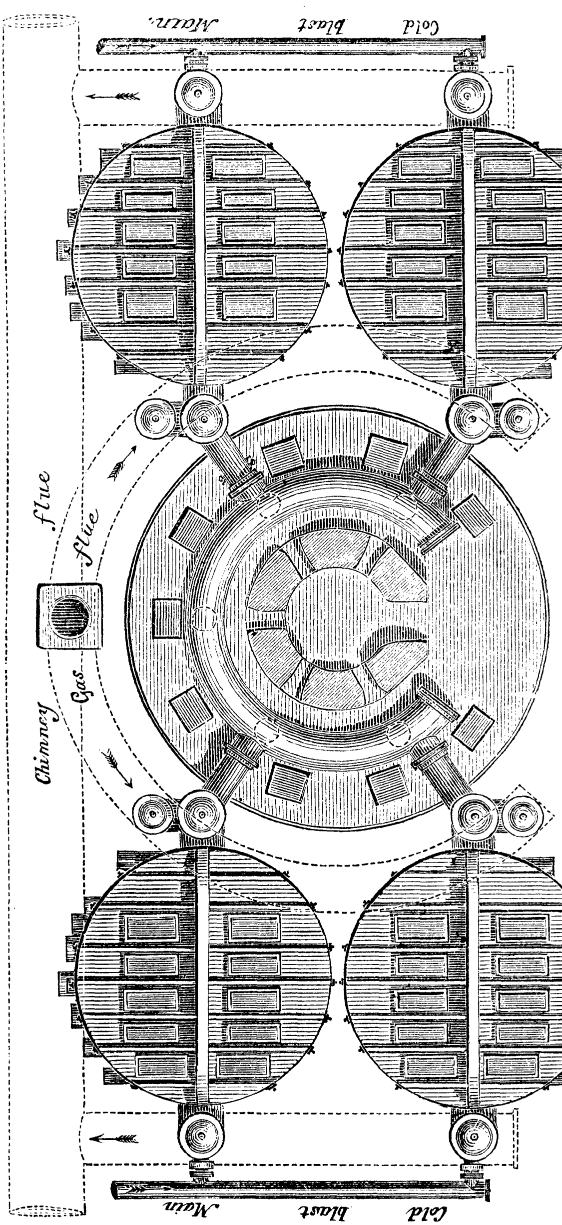


FIG. 63.—Plan of arrangement of Whitwell's stoves—Consett Works.

156. SIEMENS' DIRECT PROCESS.—Dr. C. William Siemens, of London, illustrates his newly-proposed method of producing iron and steel directly from the ore by models of the furnaces and apparatus, with specimens of the products and of the materials employed. The chemistry of iron metallurgy is indebted to Dr. Siemens for many valuable contributions, not the least of which is his lecture before the Chemical Society, in March last, upon smelting iron and steel. In that lecture he gave, in considerable detail, the course and results of the experiments which finally led him to adopt the direct process. Briefly stated, this process consists in smelting successive charges of ore in a rotary puddling furnace. A charge of about twenty hundred-weight of crushed ore mixed with the proper fluxing material is placed in the rotating puddler. When, by the flame from a regenerative furnace, it has been brought to a red heat, from five to six hundred-weight of small coal is added and the speed of the puddler is increased. The reduction of the ore to the metallic state proceeds rapidly, the carbonic oxide evolved is burned within the chamber, and very little gas from the gas-producers is required. When the reduction is complete the puddler is stopped, and the fluid slag is drawn off. The puddler is then rotated rapidly; the iron is collected into two or three metallic balls, which are withdrawn and treated in the usual way. About two hours are required for a charge, and assuming that one thousand pounds of iron are got out to each charge, the furnace would produce about five tons of puddled bar per diem. It is claimed to be feasible to push the operation so far within the rotator as to produce cast-steel. Mr. Siemens claims and undertakes to demonstrate that by this process a very great saving of fuel is effected. For the lining of the rotary puddler, after numerous trials, he has found a mixture of calcined bauxite powder with clay and plumbago to be the best. Three per cent. of clay and six per cent. of plumbago give the best results as binding materials. Bauxite is a ferruginous clay, containing from one to four per cent. of silica. The graphite, under the intense heat, reduces the oxide of iron in the bauxite to the metallic state. Linings so made have been found to be very durable, far more so than the best fire-brick.

As Dr. Siemens' papers have been extensively published and circulated,* it is unnecessary to give more than this general notice of his process. Experiments are yet in progress at his experimental works in Birmingham, to which a special visit was made by the writer.

157. DECORATED TIN-PLATE.—The Tin-Plate Decorating Company, of Neath, England, made a considerable display of tin-plate covered with a great variety of designs and of various colors. Such plates are supplied of any required design, at only a moderate increase of cost over ordinary tin-plate. They are already largely introduced for small boxes and cases for medicines, matches, spices, and the like. It is claimed by the manufacturers that the colors are indelibly printed by a

* See Jour. of the Iron and Steel Institute, 1873, i, p. 37.

patented process, and that they can be varied at pleasure, will resist the action of boiling acid, and are neither affected by heat nor cold.

For small parcels decorated plates possess the advantage of being cheaper than the ordinary paper-labeled canister, and goods so packed are preferred by dealers, as the covering is not liable to damage from either dust or damp; the empty package, moreover, presents a perpetual advertisement of its former contents.

For show-cards this article is particularly adapted, as the covering will resist the weather and they can be produced at a lower cost than the card-board designs in ordinary use, the expense of glass and framing and the risk of breaking or damage being entirely avoided.

CHAPTER VIII.

UNITED STATES.

Representation at the exhibition not thorough; Lake Superior ores; Production of the Lake Superior region; Exhibition of cast-steel by Park Brother & Co.; Iron-ores of Essex County, New York; Ores from Pennsylvania, Indiana, and Alabama; Rothwell's Wyoming map; Sellers' puddling-machine; Sellers' high rolls; Production of pig-iron in the United States; Rolled iron; Production of rails and of Bessemer and other kinds of steel; Statistical tables of production in the United States.

158. There are a few specimens of American iron-ores at the Exhibition, enough to direct attention to the fact that we are an iron-producing country, but the exhibition is by no means commensurate with our wealth and production of iron and of steel. There are withal no statistics, in a presentable form; nothing to satisfy the desire of inquirers concerning the extent and distribution of the iron and the coal of the country. The catalogue is equally barren. There does not appear to be a specimen of Bessemer or Martin's steel from the United States; and a stranger to our metallurgical industries, judging of the country by what he finds in the Exhibition, would infer that such advanced methods of producing steel are not yet introduced. But there is one exception, of crucible steel; the Messrs. Park, Brother & Co., of Pittsburgh, have sent a few samples and a very fine specimen of hot flanging for a boiler-head, which attracted the attention of the jury and received a medal.

159. Lake Superior ores.—Mr. George R. Tuttle, of Cleveland, Ohio, forwarded a very good series of blocks of the magnetic and specular ores of the Lake Superior region, as received by water-transportation at Cleveland from Marquette. The size and evident purity of these specimens attracted attention. This exhibition would be much more instructive if accompanied by photographs or models of the mines and statistics of the production. The production, which was some 7,000 tons in the year 1856, increased to over a million of tons in the year 1873.

The following is a list of the chief iron mines upon Lake Superior, with the production in the year 1874, compiled by the editor of the *Marquette Mining Journal*, and cited by the secretary of the American Iron and Steel Association:

Production of Lake Superior Mines, 1874.

Mine.	Tons.	Mine.	Tons.
Jackson	105,600	Winthrop	8,242
New York	77,010	Shenango	7,549
Cleveland	108,580	Saginaw	45,486
Lake Superior	114,074	Carr	948
Champion	46,769	Bagaley	541
Washington	28,390	Howell Hoppock	966
Republic	126,956	Emma	726
Kloman	35,088	Goodrich	3,100
Cascade	16,931	Home	2,139
Barnum	41,403	Rolling Mill	16,643
Foster	3,318	Teal Lake	2,610
Salisbury	7,480	Excelsior	1,065
Lake Angeline	31,526	Williams	593
Pittsburgh and Lake Superior	1,362	Allen	130
Edwards	2,849	Stewart	305
Spurr Mountain	42,068	Gilmore	162
Michigamme	45,294	Miller	1,717
Keystone	5,227		
McComber	2,641	Total	935,488

The decrease in the shipments of 1874, as compared with the shipments of 1873, was 231,891 tons, the production of the year last named being 1,167,379 tons. The product of 1874 was almost as large as that of 1872, which was 952,055 tons. Below is a table showing the aggregate yield of all the mines from 1856 to 1874:

1856	7,000	1867	466,076
1857	21,000	1868	507,813
1858	31,035	1869	633,238
1859	65,679	1870	856,471
1860	116,908	1871	813,379
1861	45,430	1872	952,055
1862	115,721	1873	1,167,379
1863	185,257	1874	935,488
1864	235,123		
1865	196,256		
1866	296,972	Total	7,648,280

In the year 1873, the price of Lake Superior ores at Cleveland was about $12 before the monetary panic, and $10 after it. In 1874 the price receded to about $9, and then to $7 and $7.50.

160. Cast Steel of Park, Brother & Co.—The samples of crucible-steel boiler-plate, sent by Messrs. Park, Brother & Co., were manufactured by them at their establishment, known as the "Black Diamond Steel Works," in Pittsburgh, Pa.

The exhibition is confined to several specimens of homogeneous steel boiler-plate, showing the strength, ductility, and flanging capacity of the metal. This class of material produced in these works has already been used, to some extent, on European railways, and by other railways abroad supplied with American locomotive engines, in the construction of which the "Black Diamond" steel has been used.

This firm of Park, Brother & Co. was organized early in the year 1862, and the erection of the works was commenced immediately thereafter. Their business is the manufacture of all descriptions of bar, plate, and sheet cast-steel, and, in addition, the German or "converted steel." The process of manufacture originally adopted is that which is still in operation—the "cementation process." In the production of cast-steel at these works neither the Bessemer, "Siemens-Martin," or other kindred methods have been used, their operations having been confined exclusively to crucible melting.

Among the many grades of steel produced the following may be enumerated: Best cast-steel, for machinists' and edge tools, for mining-drills, dies, &c.; steel suitable for reaping and mowing machines, plows, cultivators, and other agricultural implements; homogeneous steel-plates for locomotive, stationary, and marine steam-boilers; steel for cotton, woolen, and other machinery, together with grades suitable for the manufacture of files, cutlery, springs, saws, &c.

The leading specialties of this establishment are best cast-steel homogeneous plates, file-steel, sheet cast-steel for reaper and mower knives, together with certain other grades for various purposes.

The establishment is one of the largest in the steel trade of this country, occupying several acres of land, and possessing extensive mechanical appliances for the effective prosecution of their extensive and increasing business.

The average number of men directly employed is 400, and the productive capacity of the works is 10,000 tons annually. The manufacture in the United States of the highest grades of cast-steel is claimed to have been first fully developed in these works.

The firm has participated with advantage in most of the great exhibitions. It received a gratifying award at Paris in 1867. They have exhibited at London, Boston, Cincinnati, New Orleans, and other cities, receiving in the aggregate ten or twelve medals. At this Vienna exhibition the jury has decreed a medal.

161. IRON ORES OF ESSEX COUNTY, NEW YORK.—The rich magnetic iron-ores of the northern part of the State of New York are represented by specimens sent by Messrs. Witherbee & Sherman from Port Henry, on Lake Champlain. Among the specimens there are several fine octahedral crystals of magnetite from the "New Bed," so called; masses from the old Sanford ore-bed, and from other beds tributary to the manufacture of iron at Port Henry. No statistics given.

C. S. Johnston, of New York City, contributes a well-prepared series of specimens of the ores of the Clifton Iron Mine collected by Professor Silliman at the locality. They are accompanied by samples of the flux, the pig-metal, and small blooms, and by a short description in print, giving the results of analyses. From this description it appears that the property of this company consists of three-quarters of the town of Clifton, Saint Lawrence County, New York, and embraces about 23,000

acres of land, most of it densely wooded, through which the Grass River flows about nine miles, affording numerous and unfailing water-powers of from 10 to 35 feet fall.

The greater portion of the wood on the entire tract is hard, composed of beech, maple, birch, and cherry, interspersed with pine, spruce, tamarack, hemlock, ash, and cedar.

The mines include several extensive deposits of magnetic ores, lying mainly above water-level. At the principal bed the veins have been opened at several points, and about 15,000 tons of ore taken therefrom have been converted into neutral iron, and used for admixture with "red short" ores, with very satisfactory results.

The ores are said to yield from 50 to 65 per cent. of iron of remarkable tenacity and specially adapted for wire and crucible steel and for foundery purposes. Their purity and general characteristics are shown by the following analyses of average samples by Professor Chandler, of the Columbia College School of Mines, New York, October, 1872:

The samples of magnetic iron-ore from Prof. B. Silliman, marked "All parts Whim shaft, Arendal vein," submitted to me for examination, contain—

Magnetic oxide of iron	79.29
Oxide of manganese	0.35
Alumina	3.45
Lime	4.46
Magnesia	3.09
Sulphur	0.35
Phosphoric acid	0.32
Silicic acid	8.32
Water	0.51
	100.14

Equivalent to—

Metallic iron	57.42
Metallic manganese	0.23
Phosphorus	0.14
Sulphur	0.35

No. 7, MAGNETIC, (above lower tunnel.)

Magnetic oxide of iron	80.91
Oxide of manganese	0.42
Sulphur	0.08
Phosphoric acid	0.03
Silicic acid	8.77

Equivalent to—

Metallic iron	58.59
Metallic manganese	0.29
Phosphorus	0.01
Sulphur	0.08

TOOLEY LAKE, (new discovery.)

Magnetic oxide of iron	75.01
Oxide of manganese	0.42
Sulphur	0.08
Phosphoric acid	0.03
Silicic acid	13.34
Equivalent to—	
Metallic iron	54.32
Metallic manganese	0.29
Phosphorus	0.01
Sulphur	0.08

SHERIDAN VEIN, (new discovery.)

Magnetic oxide of iron	79.83
Oxide of manganese	0.72
Sulphur	0.41
Phosphoric acid	trace.
Silicic acid	8.55
Equivalent to—	
Metallic iron	57.81
Metallic manganese	0.50
Phosphorus	trace.
Sulphur	0.41

A good wagon-road about twenty-two miles long leads from the property to De Kalb Junction, on the Rome, Watertown and Ogdensburg Railroad, nineteen miles from Ogdensburg. A nearer route to Ogdensburg is projected.

162. ORES FROM PENNSYLVANIA, INDIANA, AND ALABAMA.—E. C. Pechin, esq., of the Dunbar furnace, Fayette County, Pennsylvania, sends a neatly arranged collection of the ores, coal, coke, and iron. The specimens are placed in a box with partitions, and the description of the specimens is added in gilded letters.

There are also specimens of Connelsville coke and coal, sent by Prof. Amasa McCoy and Philo Norton.

Prof. E. C. Cox, the State geologist of Indiana, makes a fine display of "block-coal," of iron-ore, and of pig-iron, all from the southern part of the State.

Colonel Wilder, of Chattanooga, Tenn., arrived late with an enormous block of iron-ore, large blocks of coal, blooms, pig-iron, bar-iron, &c. This collection made a fine display, and was honored by a medal.

163. ROTHWELL'S WYOMING MAP.—The iron resources of Alabama are merely indicated by a few small specimens. This is also the case with North Carolina and a few other States. Mr. R. P. Rothwell forwarded some of the Alabama ores, and also contributed one of his large maps of the Wyoming anthracite coal-fields. This map, which required years of patient labor, was presented, at the close of the Exhibition, to the engineer department of Belgium.

164. SELLERS' PUDDLING MACHINE.—The rotatory puddler exhibited by Mr. William Sellers, of Philadelphia, has, from the first, attracted great attention. The novelty of its form, the single opening in front, its compactness and finish, and the ease with which it is manipulated,

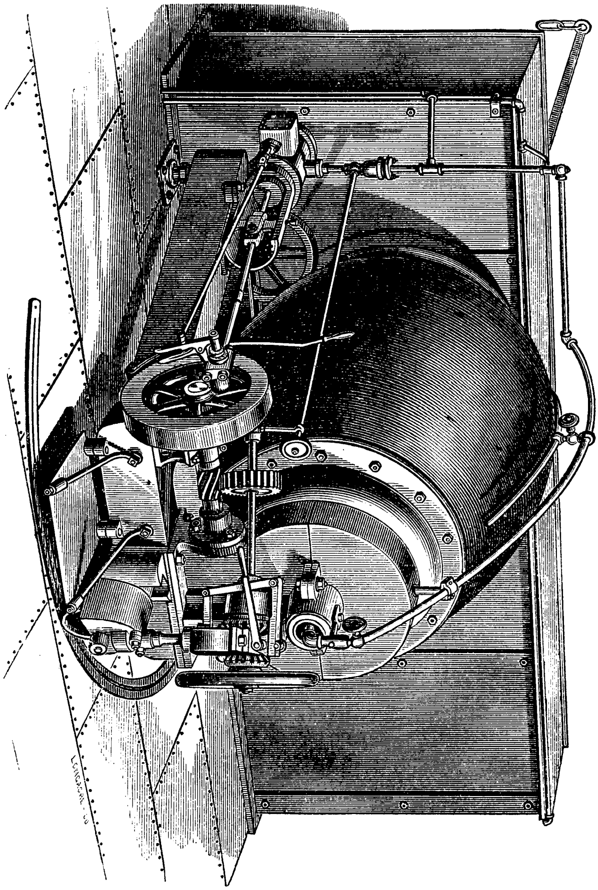


FIG. 64.—SELLERS'S ROTARY PUDDLER.

all commend it to the notice of iron-men. It is flask-shaped. The flame passes in, circulates, and passes out again at the same end by which it entered, on the opposite side of a horizontal partition which divides the opening. All the other rotatory puddlers have openings at the opsite ends, one of which is closed by a sliding-door, and is used for charging and discharging. The puddler is so placed upon a frame that it can be swung away from the furnace to permit of charging from the front. The parts most exposed to the heat are protected on the outside by water-jackets. The charges for this puddler are to be melted in an auxiliary furnace, saving not only the lining of the puddler, but time and fuel.

In detail, Mr. William Sellers's rotary puddling-machine, which was shown in full size and in motion, consists primarily of a cast-iron spheroidal vessel, or furnace, rotating about its longer axis, which is sup-

ported in a horizontal plane. It is closed, at one end, by a water-back, and is open at the other for the reception of the charge of metal, and for the admission of the gases in combustion.

This puddling "bowl," as it is termed, is mounted on a cast-iron frame or carriage, which also supports the steam-engine that drives the machinery to rotate the bowl and to move the frame about its axis. The frame is supported on three points; a pintle or hinge, and two wheels placed with their axes radial to the pintle. The bowl of the puddling-machine, when working, has its open end in contact with an opening of similar size in the front plate of a stack of flues. This opening, when exposed to view, shows the mouths of a number of flues; the upper ones conveying the gas and heated air to the bowl, while a larger opening below—the "down take"—carries off the products of combustion, and leads them to the "regenerative" system below the floor. At the mouths of the upper flues the air and gases mingle together, and, when ignited, enter the bowl, are driven to its back end, there reverberating, pass over its lower half, and escape through the "down-take," thus filling the bowl with an intensely hot flame.

The bowl is lined or fettled with lumps of refractory iron-ore, built in, like rough stone-work, with some quick-setting cement.

The "water-back," which forms one end of the bowl, has a projecting journal resting in a bearing, while the other end of the bowl is supported on friction-rollers in the frame.

The journal on the water-back is hollow, and through it passes a pipe, having one end (that within the water-back) turned up in a nozzle, from which the water in escaping is thrown in a jet against the upper surface of the water-back, and, filling its lower half, flows out through the hollow journal into a water-pan, and is from thence carried away in pipes. The lower half of the water-back being always filled with water, during each rotation of the bowl all parts of the iron back are, in turn, immersed, and thus kept cool. The exterior surface of the bowl is cooled by jets of water falling from a sprinkler placed over it.

An engine on one side of the frame turns a worm or tangent wheel, which gears into a worm-wheel attached to the water-back, and serves to rotate the bowl.

A spiral pinion on the engine-shaft drives a train of wheels which imparts motion, in either direction, to one of the supporting-wheels, upon which the frame moves. By means of this connection the frame can be made to turn about the fixed pintle, like a door on its hinges, alternately closing the flue-openings with the mouth of the bowl, or exposing them to view when it is drawn away from the stack.

When open, or away from the stack, the interior of the bowl is accessible from its open end for repairs or inspection, for the introduction of the charge of metal, or for the removal of the puddled ball. When closed it is in position to receive the burning gas as it escapes from the flues. To prevent the stack of flues from cooling during the charging

of the bowl, a circular, concave lid, lined with fire-brick and hung conveniently to a crane, is swung against the aperture in the iron plate on the stack usually covered by the bowl.

The cylinder of the operating steam-engine is immediately over the pintle about which the frame turns. The various pipes for water and steam are all connected with one stand, and are jointed in line with the center of the pintle, and provided with proper stuffing-boxes to permit them to turn with ease.

A platform at the back of the frame is provided for the engine-man. Standing on this he has within easy reach the throttle-valve, a friction-brake, (for sudden stopping,) a lever to operate the opening and closing attachments, and, also, a reversing-lever, enabling the engine to run backward or forward. A balance-wheel is provided to open and close the mouth of the bowl by hand.

The flue-stack against which the puddler-bowl closes is merely a rectangular iron casing, within which are constructed the various flues required for the heated air, the gas, and the down-take to the regenerator. A door at the back of the flue-stack can be opened for the ready inspection of the interior of the bowl while it is at work and under heat. In practice the charge having been introduced into the puddler, and its mouth brought up to the flue-stack, the ignited gas and air are admitted, and burning within the rotating-bowl, act upon the molten metal lying in the bottom of the bowl. The rotation stirs up the metal, which, boiling, "comes to nature," and is aggregated by the tumbling together of the particles of wrought iron. After this the surplus cinder can be drawn off through a tap-hole. The bowl being then turned away from the flues, the puddled ball can be readily taken out and carried to the squeezer or hammer.

If the iron be charged as pig, the bowl is not rotated until the metal has melted; but if the charge is drawn melted from a cupola, puddling may begin as soon as the bowl is brought up against the stack and the gases are admitted.

The international jury awarded a Medal of Merit.

165. Sellers's high rolls.—A set of high rolls from the same establishment also deserves special mention. By a simple hydraulic arrangement these rolls can be set instantly at any required distance apart. A man, at one point, by a lever, controls the movement. Perfect parallelism is maintained and, in case of clogging, the rolls can be separated without accident.

IRON PRODUCTION OF THE UNITED STATES.

166. Production of pig and rolled iron.—In concluding this brief notice of the objects from the United States at Vienna, it is deemed advisable to supplement it by a brief statement of the iron-industry of the country at that period. The growth of the pig-iron branch of the iron-trade from 1854 to 1874 is shown by the following table, supplied

to the author by Mr. Swank, who has compiled it from statistics procured by the American Iron and Steel Association.*

Production of pig-iron in the United States, in net tons.

Years.	Anthracite.	Charcoal.	Bituminous coal and coke.	Total.
1854	339, 435	342, 298	54, 485	736, 218
1855	381, 886	339, 922	62, 390	784, 178
1856	443, 113	270, 470	69, 554	883, 137
1857	390, 385	330, 321	77, 451	798, 157
1858	361, 430	285, 313	58, 351	705, 094
1859	471, 745	284, 041	84, 841	840, 627
1860	519, 211	278, 331	122, 228	919, 770
1861	409, 229	195, 278	127, 037	731, 544
1862	470, 315	186, 660	130, 687	787, 662
1863	577, 638	212, 005	157, 961	947, 604
1864	684, 018	241, 853	210, 125	1, 135, 996
1865	479, 558	262, 342	189, 682	931, 582
1866	749, 367	332, 580	268, 396	1, 350, 343
1867	798, 638	344, 341	318, 647	1, 461, 626
1868	893, 000	370, 000	340, 000	1, 603, 000
1869	971, 150	392, 150	553, 341	1, 916, 641
1870	930, 000	365, 000	570, 000	1, 865, 000
1871	956, 608	385, 000	570, 000	1, 912, 608
1872	1, 369, 812	500, 587	984, 159	2, 854, 588
1873	1, 312, 754	577, 620	977, 904	2, 868, 278
1874	1, 202, 144	576, 557	910, 712	2, 689, 413

The following tables, from the same source, present a general view of the production of all forms of rolled iron in the country during the year 1874, the production of rails and of Bessemer steel. In the table of rolled iron all forgings, such as anchors, anvils, hammered axles, cranks, ships' knees, &c., are carefully excluded, owing to the difficulty of getting exact returns.

Production of rolled iron, 1874.

States.	Bar, angle, bolt, rod, and hoop iron.	Plate and sheet iron.	Cut-nails and spikes.	Iron and steel rails, all sizes.	Total rolled iron.
Maine	3, 994			14, 650	18, 644
New Hampshire	300				300
Vermont				10, 400	10, 400
Massachusetts	40, 324	6, 592	28, 819	24, 765	100, 500
Rhode Island	7, 170		3, 446		10, 616
Connecticut	11, 921				11, 921
New York	76, 590	4, 000	5, 949	46, 979	133, 518
New Jersey	24, 645	2, 256	27, 643	3, 537	58, 081
Pennsylvania	343, 632	120, 098	75, 151	259, 288	798, 169
Delaware	6, 860	4, 958			11, 818
Maryland	8, 455	12, 428		48, 008	68, 891
Virginia	11, 086		5, 602		16, 688
Georgia	1, 406			8, 061	9, 467
Alabama	1, 000				1, 000
West Virginia	1, 609		54, 201	522	56, 332
Kentucky	18, 239	5, 120	5, 121	6, 068	34, 548
Tennessee	1, 573		660	13, 693	15, 926
Ohio	105, 413	5, 143	27, 253	82, 561	220, 370
Indiana	7, 376		7, 514	20, 617	35, 507
Illinois	2, 500	2, 240	4, 250	125, 103	134, 093
Michigan	4, 207	1, 553		2, 448	8, 208
Wisconsin	275			29, 680	29, 955
Missouri	1, 500	10, 870		24, 017	36, 387
California	9, 205			7, 016	16, 221
Kansas				2, 000	2, 000
Total	689, 280	175, 258	245, 609	729, 413	1, 839, 560

*Vide report of the secretary of the American Iron and Steel Association, January 1, 1875.

Secretary Swank states: "The total production of all rolled iron in 1874, Bessemer steel rails included, was 1,839,560 net tons, against 1,966,445 tons in 1873, a decrease of only 126,885 tons. This decrease was all in rails. Of the total product of the rolling-mills in 1874, 1,110,147 tons were rolled iron other than rails, against 1,076,368 tons in 1873, an increase of 33,779 tons. The number of tons of nail-plate consumed in 1874 was 245,609 net tons, against 201,235 tons in 1873, an increase of 44,374 tons. The increase of 33,779 tons in the aggregate production of rolled iron other than rails in 1874 was, therefore, wholly in the department of cut-nails and spikes. The total number of cut-nails and spikes produced in 1874 was 4,912,180, against 4,024,704 kegs in 1873."

In the production of rails the State of Pennsylvania takes the lead, but in a rapidly diminishing degree from year to year since 1871.

Production of rails by States, in tons.

States.	1871.	1872.	1873.	1874.
Pennsylvania	335, 604	419, 529	328, 522	259, 288
Illinois	91, 178	106, 916	136, 102	125, 103
Ohio	75, 782	121, 923	130, 326	82, 561
New York	87, 022	82, 457	59, 764	46, 970
Maryland	44, 941	26, 472	42, 356	48, 008
Wisconsin	28, 774	37, 284	39, 495	29, 680
Massachusetts	28, 864	29, 242	34, 034	24, 765
Indiana	12, 778	23, 893	26, 579	20, 617
Maine	13, 383	14, 058	16, 500	14, 650
Missouri	8, 200	15, 500	14, 020	24, 017
Tennessee	9, 667	14, 620	13, 973	13, 693
New Jersey	6, 700	9, 185	13, 749	3, 537
Kentucky	6, 000	4, 000	11, 386	6, 068
Georgia	7, 840	6, 930	8, 275	8, 061
Michigan	14, 000	9, 883	4, 433	2, 448
West Virginia	5, 000	20, 100	4, 000	522
Vermont	....	....	6, 088	10, 400
California	....	....	475	7, 016
Kansas	....	....	....	2, 000
	775, 733	941, 992	890, 077	729, 413
Street, mine, and light rails	....	58, 008	....	....
Total	775, 733	1, 000, 000	890, 077	729, 413

In 1874 there were eight completed Bessemer steel establishments, and the combined product of steel rails exceeded that of 1873, being 144,944 net tons in 1874 against 129,015 net tons in 1873.

Product of Bessemer steel rails, 1867 *to* 1874.

1867	2, 550	1871	38, 250
1868	7, 225	1872	94, 070
1869	9, 650	1873	129, 015
1870	34, 000	1874	144, 944

The annual production of merchantable Bessemer steel, for all purposes, is as follows:

1867	3, 000	1871	45, 000
1868	8, 500	1872	110, 500
1869	12, 000	1873	157, 000
1870	40, 000	1874	176, 579

There were forty-two establishments in the year 1874 producing other kinds of steel than Bessemer, including cast, puddled, blister, and open-hearth steel. The production of the latter is steadily increasing, amounting in 1874 to 7,000 tons, against 3,500 tons in 1873, and 3,000 tons in 1872. The total production of crucible-steel in the United States in 1874 is stated approximately as 34,128 tons, and of puddled, open-hearth, and blister steel as 13,353 tons.

Production of pig-iron in 1872, 1873, *and* 1874, *by States.*

States.	No. of stacks in blast Dec. 31, 1874.	No. of stacks out of blast Dec. 31, 1874.	No. of stacks blown out in Jan., 1875.	Whole No. completed stacks Dec. 31, 1874.	Whole No. completed stacks Dec. 31, 1873.	No. of new stacks completed in 1874.	No. of new stacks completed in 1873.	No. of new stacks completed in 1872.	No. of stacks building in 1875.	No. of stacks projected in 1875.	Make of pig-iron in 1872, net tons.	Make of pig-iron in 1873, net tons.	Make of pig-iron in 1874, net tons.
Maine	1	...	....	1	1	....	....	....	....	....	....	780	1, 661
Vermont	2	....	....	2	2	....	....	....	....	....	2, 000	3, 100	3, 450
Massachusetts	5	1	1	6	6	....	....	....	....	....	17, 070	21, 136	27, 991
Connecticut	3	7	....	10	10	....	....	....	....	....	22, 700	26, 977	14, 518
New York	37	21	7	58	53	5	4	2	2	2	291, 155	296, 818	326, 721
New Jersey	10	7	....	17	16	1	1	2	3	2	103, 858	102, 341	90, 150
Pennsylvania	142	124	15	266	162	4	14	19	19	17	1, 401, 497	1, 389, 573	1, 213, 133
Maryland	13	10	2	23	22	1	....	....	....	2	63, 031	55, 986	54, 556
Virginia	15	23	4	38	35	3	3	2	2	2	21, 445	26, 475	29, 451
North Carolina	2	6	....	8	8	....	1	....	2	2	1, 073	1, 432	1, 340
South Carolina	....	8	....	8	8	....	....	....	....	....	....	....	....
Georgia	4	6	....	10	8	2	2	....	3	2	2, 945	7, 501	9, 786
Alabama	6	8	1	14	11	3	3	....	2	3	12, 512	22, 283	32, 863
Texas	....	1	....	1	1	....	....	....	....	1	629	280	1, 012
West Virginia	5	4	....	9	6	3	1	1	2	....	20, 796	23, 056	30, 134
Kentucky	11	16	7	27	25	2	....	....	....	2	67, 396	69, 889	61, 227
Tennessee	13	9	6	22	20	2	1	1	1	6	42, 454	43, 134	48, 770
Ohio	59	34	17	93	88	6	5	6	6	8	399, 743	406, 029	425, 001
Indiana	3	5	....	8	8	....	....	2	....	1	39, 221	32, 486	13, 732
Illinois	3	7	....	10	10	....	2	....	2	1	78, 627	55, 796	37, 946
Michigan	16	18	2	34	33	1	6	4	....	6	100, 222	123, 506	136, 662
Wisconsin	5	9	....	14	13	1	3	1	....	....	65, 036	74, 148	50, 792
Minnesota	....	1	....	1	....	1	....	....	....	....	....	....	....
Missouri	8	11	....	19	18	2	4	1	1	5	101, 158	85, 552	75, 817
Oregon	1	....	....	1	1	....	....	....	....	1	....	....	2, 500
Utah	1	....	....	1	....	1	....	....	1	....	....	....	200
Total	365	336	62	*701	665	38	50	41	46	63	2, 854, 558	2, 868, 278	2, 689, 413

* Two furnaces, not included here, were abandoned in 1874; one in Ohio, and one in Missouri.

PEAT AND CHARCOAL.

Michigan	....	1	....	1	1	....	....	1	....	....	224	500	....

ANTHRACITE.

Massachusetts	1	....	....	1	1	....	....	....	....	....	4, 250	5, 432	10, 214
New York	28	13	3	41	36	5	2	1	2	2	271, 343	267, 489	298, 428
New Jersey	10	7	....	17	16	1	1	2	3	2	103, 858	102, 341	90, 150
Pennsylvania:													
Lehigh	29	18	....	47	47	...	3	3	6	....	449, 663	389, 969	316, 789
Schuylkill	30	13	4	43	40	3	3	3	5	3	232, 225	236, 409	232, 420
Upper Susquehanna	8	17	3	25	25	....	....	3	1	3	127, 260	129, 304	88, 243
Lower Susquehanna	20	17	1	37	37	....	4	1	4	4	159, 304	157, 403	137, 556
Total of Pennsylvania	87	65	8	152	149	3	10	10	16	10	968, 453	913, 085	775, 008
Maryland	3	2	....	5	4	1	....	....	....	....	21, 908	20, 407	22, 344
Virginia	1	....	....	1	1	....	....	....	....	....	....	4, 000	6, 000
Total	130	87	11	217	207	10	13	13	21	14	1, 369, 812	1, 312, 754	1, 202, 144

CHARCOAL AND BITUMINOUS COAL.

States.	No. of stacks in blast Dec. 31, 1874.	No. of stacks out of blast Dec. 31, 1874.	No. of stacks blown out in Jan., 1875.	Whole No. completed stacks Dec. 31, 1874.	Whole No. completed stacks Dec. 31, 1873.	No. of new stacks completed in 1874.	No. of new stacks completed in 1873.	No. of new stacks completed in 1872.	No. of stacks building in 1875.	No. of stacks projected in 1875.	Make of pig-iron in 1872, net tons.	Make of pig-iron in 1873, net tons.	Make of pig-iron in 1874, net tons.
Virginia	1	2	....	3	2	1	1	....	....	....	....	2, 400	1, 340
Alabama	....	2	....	2	2	....	....	....	....	....	....	....	2, 400
Total	1	4	....	5	4	1	1	....	....	....	....	2, 400	3, 740

BITUMINOUS COAL AND COKE.

States.	No. of stacks in blast Dec. 31, 1874.	No. of stacks out of blast Dec. 31, 1874.	No. of stacks blown out in Jan., 1875.	Whole No. completed stacks Dec. 31, 1874.	Whole No. completed stacks Dec. 31, 1873.	No. of new stacks completed in 1874.	No. of new stacks completed in 1873.	No. of new stacks completed in 1872.	No. of stacks building in 1875.	No. of stacks projected in 1875.	Make of pig-iron in 1872, net tons.	Make of pig-iron in 1873, net tons.	Make of pig-iron in 1874, net tons.
Pennsylvania:													
Shenango Valley	16	16	....	32	31	1	2	5	....	1	160, 188	160, 831	156, 419
Allegheny County	5	6	1	11	11	....	....	4	1	2	110, 599	158, 789	143, 660
Miscellaneous	13	19	....	32	32	....	1	....	2	4	117, 224	111, 014	97, 968
Total of Pennsylvania	34	41	1	75	74	1	3	9	3	7	388, 011	430, 634	397, 147
Maryland	....	4	....	4	4	....	....	....	....	2	12, 079	5, 264	7, 209
Virginia	....	....	....	....	....	....	....	....	1	....	....	....	....
North Carolina	....	....	....	....	....	....	....	....	1	....	....	....	....
Georgia	1	....	....	1	1	....	1	....	....	....	....	....	5, 516
West Virginia	3	2	....	†5	2	2	....	1	1	....	19, 846	21, 106	26, 734
Kentucky	3	1	1	4	3	1	....	....	....	....	27, 697	27, 670	24, 583
Tennessee	2	2	....	4	3	1	1	1	1	3	8, 360	8, 602	11, 543
Ohio:													
Hanging Rock	3	7	....	10	7	3	1	1	5	3	23, 169	28, 601	26, 015
Mahoning Valley	17	11	8	28	28	....	1	2	....	....	200, 785	157, 888	154, 287
Miscellaneous	11	7	1	18	16	2	3	3	1	5	80, 167	119, 042	151, 864
Total of Ohio	31	25	9	56	51	5	5	6	6	8	304, 121	305, 531	332, 166
Indiana	3	4	....	7	7	....	....	2	....	1	39, 221	32, 486	11, 632
Illinois	3	7	....	10	10	....	2	....	2	1	78, 627	55, 796	37, 946
Michigan	1	2	....	3	3	....	....	....	....	....	13, 382	795	3, 672
Missouri	....	8	....	8	‡9	....	2	1	1	2	55, 569	46, 016	26, 724
Total	81	96	11	177	167	10	14	20	16	24	946, 913	933, 900	884, 872

† One stack altered from charcoal. ‡ One stack torn down.

CHARCOAL.

States.	No. of stacks in blast Dec. 31, 1874.	No. of stacks out of blast Dec. 31, 1874.	No. of stacks blown out in Jan., 1875.	Whole No. completed stacks Dec. 31, 1874.	Whole No. completed stacks Dec. 31, 1873.	No. of new stacks completed in 1874.	No. of new stacks completed in 1873.	No. of new stacks completed in 1872.	No. of stacks building in 1875.	No. of stacks projected in 1875.	Make of pig-iron in 1872, net tons.	Make of pig-iron in 1873, net tons.	Make of pig-iron in 1874, net tons.
Maine	1	....	....	1	1	....	....	....	....	....	....	780	1,661
Vermont	2	....	....	2	2	....	....	....	....	....	2,000	3,100	3,450
Massachusetts	4	1	1	5	5	....	....	....	....	....	12,820	15,704	17,777
Connecticut	3	7	....	10	10	....	....	....	....	....	22,700	26,977	14,518
New York	9	8	4	17	17	....	2	1	....	....	19,812	29,329	28,293
Pennsylvania	21	18	6	39	39	....	1	....	....	....	45,033	45,854	40,978
Maryland	10	4	2	14	14	....	....	....	....	....	29,044	30,315	25,003
Virginia	13	21	4	34	32	2	2	2	1	2	21,445	20,075	22,111
North Carolina	2	6	....	8	8	....	1	....	1	2	1,073	1,432	1,340
South Carolina	....	8	....	8	8	....	....	....	....	....	....	....	....
Georgia	3	6	....	9	7	2	1	....	3	2	2,945	7,501	4,270
Alabama	6	6	1	12	9	3	3	....	2	3	12,512	22,283	30,463
Texas	....	1	....	1	1	....	....	....	....	1	619	280	1,012
West Virginia	2	2	....	4	4	1	1	....	1	....	950	1,950	3,400
Kentucky	8	15	6	23	22	1	....	....	....	2	39,699	42,219	36,644
Tennessee	11	7	6	18	17	1	....	....	....	3	34,094	34,532	37,227
Ohio:													
Hanging Rock	28	6	8	34	33	1	....	....	....	....	87,440	92,365	85,873
Miscellaneous	....	3	....	3	§4	....	....	....	....	....	8,182	8,133	6,962
Total of Ohio	28	9	8	37	37	1	....	....	....	....	95,622	100,498	92,835
Indiana	....	1	....	1	1	....	....	....	....	....	....	....	2,100
Michigan	15	14	2	29	28	1	6	2	....	6	86,616	113,475	128,969
Wisconsin	4	7	....	11	10	1	2	1	....	....	27,790	38,880	28,973
Minnesota	....	1	....	1	....	1	....	....	....	....	....	....	....
Missouri	8	3	....	11	9	2	2	....	....	3	45,589	39,536	49,093
Oregon	1	....	....	1	1	....	....	....	....	1	....	....	2,500
Utah	1	....	....	1	....	1	....	....	1	....	....	....	200
Total	152	145	40	297	282	17	21	6	9	25	500,363	574,720	572,817

§ One stack abandoned in 1874.

ANTHRACITE COAL AND COKE.

Wisconsin	1	2	....	3	3	....	1	....	....	....	37,246	35,268	21,819
Michigan	....	1	....	4	1	....	....	1	....	....	....	8,736	4,021
Total	1	3	....	4	4	....	1	1	....	....	37,246	44,004	25,840

RECAPITULATION.

Charcoal	152	145	40	297	282	17	21	6	9	25	500,363	574,720	572,817
Bituminous coal and coke	81	96	11	177	167	10	14	20	16	24	946,913	933,900	884,872
Anthracite	130	87	11	217	207	10	13	13	21	14	1,369,812	1,312,754	1,202,144
Anthracite coal and coke	1	3	....	4	4	....	1	1	....	....	37,246	44,004	25,840
Peat and charcoal	....	1	....	1	1	....	....	1	....	....	224	500	....
Charcoal and bituminous coal	1	4	....	5	4	1	1	....	....	....	....	2,400	3,740
Total	365	336	62	‖701	665	38	50	41	46	63	2,854,558	2,868,278	2,689,413

‖ Two furnaces, not included here, were abandoned in 1874.

Stock of pig-iron unsold December 31, 1874.

States and districts.	Anthracite, net tons.	Bituminous coal and coke, net tons.	Bituminous coal and charcoal, net tons.	Charcoal, (low grade,) net tons.	Charcoal, (car-wheel,) net tons.	Total, net tons.
New England¶ and New York	101, 096	....	....	10, 680	26, 448	138, 224
New Jersey	37, 959	....	....	....	....	37, 959
Pennsylvania:						
Charcoal	....	....	....	11, 225	10, 308	21, 533
Lehigh Valley	28, 791	....	....	....	....	28, 791
Schuylkill	40, 787	....	....	....	....	40, 787
Upper Susquehanna	12, 868	....	....	....	....	12, 868
Lower Susquehanna	22, 990	....	....	....	....	22, 990
Shenango	....	87, 650	....	....	....	87, 650
Allegheny County	....	12 230	....	....	....	12, 230
Miscellaneous	....	15, 591	....	....	....	15, 591
Total for Pennsylvania	105, 436	115, 471	....	11, 225	10, 308	242, 440
Maryland	4, 497	3, 853	....	1, 221	6, 387	15, 958
Southern States	....	1, 008	2, 981	17, 235	17, 818	39, 042
West Virginia	....	5, 601	....	870	2, 500	8, 971
Kentucky	....	8, 080	....	20, 657	4, 255	32, 992
Tennessee	....	2, 781	....	23, 765	1, 220	27, 766
Ohio:						
Hanging Rock	....	11, 450	....	50, 717	7, 580	69, 747
Mahoning Valley	....	25, 777	....	....	....	25, 777
Miscellaneous	....	11, 952	....	10, 608	....	22, 560
Total for Ohio	....	49, 179	....	61, 325	7, 580	118, 084
Michigan and Indiana**	....	8, 796	....	53, 558	4, 333	66, 687
Illinois	....	7, 229	....	....	....	7, 229
Wisconsin	....	....	....	8, 699	439	9, 138
Missouri	....	11, 500	....	38, 764	1, 030	51, 294
Grand total	248, 988	213, 498	2, 981	247, 999	82, 318	795, 784

¶ New England has but one anthracite furnace. ** Indiana has but one charcoal furnace.

Imports of iron and steel and manufactures thereof into the United States from all countries during the fiscal years 1871 to 1875.—Gold values.

Commodities.	1871.		1872.		1873.		1874.		1875.	
	Net tons.	Values.	Net tons.	Values.	Net tons.	Values.	Net tons.	Values.	Net tons.	Values.
Pig-iron	199, 515	$3, 106, 490	277, 232	$5, 122, 318	241, 355	$7, 203, 769	103, 086	$3, 288, 022	60, 198	$1, 457, 941
Castings	2, 203	32, 679	433	34, 333	364	32, 113	215	15, 905	87	3, 368
Bar-iron	101, 751	4, 058, 126	118, 227	5, 153, 472	83, 008	5, 288, 481	38, 515	3, 022, 311	26, 552	1, 728, 137
Boiler-iron	549	31, 284	700	57, 392	587	55, 030	77	11, 177	64	9, 229
Band, hoop, and scroll iron	11, 220	506, 501	11, 708	573, 457	12, 830	846, 973	3, 007	200, 574	429	24, 062
Railroad bars or rails of iron	513, 022	17, 360, 297	472, 365	15, 778, 941	240, 504	10, 541, 036	20, 379	987, 260	2, 198	69, 284
Railroad bars or rails of steel*	....	....	122, 955	6, 277, 694	160, 041	9, 199, 666	146, 410	9, 771, 175	44, 934	2, 863, 027
Sheet-iron	10, 488	610, 809	14, 754	1, 116, 200	14, 943	1, 287, 072	6, 166	808, 016	5, 358	852, 426
Old and scrap iron	174, 502	3, 782, 526	258, 455	6, 040, 678	228, 567	6, 643, 512	57, 530	1, 495, 142	36, 298	792, 772
Hardware	....	141, 495	....	204, 992	....	371, 518	....	265, 678	....	311, 807
Anchors, cables, and chains of all kinds	5, 525	472, 782	5, 505	490, 275	5, 799	675, 184	3, 498	437, 582	2, 892	339, 806
Machinery	....	907, 371	....	1, 054, 045	....	1, 693, 966	....	1, 293, 774	....	697, 100
Muskets, pistols, rifles, and sporting-guns	....	706, 988	....	711, 858	....	822, 119	....	873, 430	....	655, 204
Steel ingots, bars, sheets, and wire	....	3, 750, 702	....	4, 033, 508	....	4, 155, 234	....	2, 960, 055	....	2, 539, 906
Cutlery	....	1, 956, 351	....	2, 143, 708	....	2, 234, 355	....	1, 586, 194	....	1, 440, 418
Files	....	604, 153	....	583, 058	....	770, 986	....	575, 211	....	359, 435
Saws and tools	....	514, 346	....	542, 377	....	265, 637	....	48, 210	....	24, 712
Other manufactures of iron and steel not elsewhere specified	....	4, 883, 075	....	5, 621, 882	....	7, 221, 801	....	6, 153, 830	....	4, 307, 616
Total	1, 018, 775	43, 425, 975	1, 282, 334	55, 540, 188	987, 998	59, 308, 452	378, 883	33, 793, 546	179, 010	18, 476, 250

* Previous to July 1, 1871, reported under head of iron rails.

Imports of iron and steel and manufactures thereof into the United States from all countries during the calendar years 1871 to 1874.—Gold values.

Commodities.	1871.		1872.		1873.		1874.	
	Net tons.	Values.	Net tons.	Values.	Net tons.	Values.	Net tons.	Values.
Pig-iron	245, 535	$3, 797, 298	295, 967	$7, 269, 850	154, 708	$5, 181, 847	61, 165	$1, 738, 438
Castings	441	28, 260	407	38, 564	262	19, 169	74	6, 285
Bar-iron	122, 565	5, 024, 686	89, 576	4, 837, 532	62, 253	4, 481, 614	26, 876	1, 946, 793
Boiler-iron	322	27, 351	684	59, 993	464	44, 324	53	7, 669
Band, hoop, and scroll iron	13, 098	594, 166	12, 379	748, 509	8, 245	537, 140	1, 425	91, 475
Railroad bars or rails, of iron	566, 202	19, 132, 359	381, 064	14, 498, 012	99, 201	4, 708, 189	7, 796	393, 589
Railroad bars or rails, of steel*	....	....	149, 786	8, 207, 013	159, 571	8, 984, 103	100, 486	6, 838, 875
Sheet-iron	12, 047	857, 895	10, 149	1, 263, 112	10, 713	1, 090, 486	6, 736	1, 007, 988
Old and scrap iron	220, 340	4, 845, 092	278, 257	7, 617, 463	108, 838	3, 061, 759	40, 746	949, 942
Anchors, cables, and chains of all kinds	5, 434	460, 116	5, 875	622, 908	4, 668	565, 656	3, 219	390, 619
Hardware	....	134, 427	....	325, 208	....	288, 706	....	303, 728
Machinery	....	891, 408	....	1, 148, 713	....	1, 941, 053	....	802, 570
Muskets, rifles, pistols, and sporting-guns	....	599, 388	....	811, 872	....	886, 307	....	691, 990
Steel ingots, bars, sheets, and wire	....	3, 460, 735	....	4, 106, 087	....	3, 865, 316	....	2, 678, 611
Cutlery	....	2, 051, 750	....	2, 272, 467	....	1, 989, 595	....	1, 453, 570
Files	....	595, 539	....	676, 814	....	744, 798	....	430, 688
Saws and tools	....	695, 275	....	476, 927	....	52, 509	....	32, 674
Other manufactures not specified	....	4, 724, 181	....	6, 743, 183	....	7, 322, 099	....	4, 835, 216
Total	1, 185, 984	47, 919, 926	1, 224, 144	61, 724, 227	608, 923	45, 764, 670	248, 576	24, 600, 720

* Previous to July 1, 1871, reported under the head of iron rails.

Domestic exports of iron and steel and manufactures thereof from the United States to all countries during the calendar years 1871, 1872, 1873, *and* 1874.—*Currency values.*

Commodities.	1871.		1872.		1873.		1874.	
	Quantities.	Values.	Quantities.	Values.	Quantities.	Values.	Quantities.	Values.
IRON, AND MANUFACTURES OF:								
Pig-iron .... Net tons	2, 330	$67, 481	1, 477	$72, 818	10, 103	$414, 349	16, 039	$447, 619
Bar-iron .... do	179	14, 830	329	31, 929	367	40, 404	4, 717	331, 341
Boiler-plate iron .... do	24	3, 517	33	5, 041	125	14, 519	122	13, 219
Railroad bars or rails .... do	333	23, 813	1, 212	86, 820	375	30, 743	1, 257	73, 159
Sheet, band, and hoop .... do	30	3, 518	165	13, 781	49	7, 108	86	12, 284
Castings, not specified .... do	....	126, 499	....	144, 653	....	201, 459	....	271, 276
Car-wheels .... Number	4, 043	82, 467	4, 873	97, 090	12, 274	196, 438	6, 644	137, 589
Stoves, and parts of	....	79, 909	....	101, 959	....	101, 397	....	141, 953
Steam-engines, locomotives .... Number	62	820, 943	55	774, 296	68	1, 109, 482	77	1, 145, 669
Steam-engines, stationary .... do	42	105, 857	40	89, 556	49	125, 037	41	51, 296
Boilers, separate from engines	....	114, 705	....	166, 554	....	254, 240	....	95, 604
Machinery, not specified	....	1, 890, 880	....	3, 160, 538	....	3, 011, 111	....	4, 153, 258
Nails and spikes .... Net tons	2, 355	245, 289	2, 682	322, 879	3, 409	371, 663	5, 139	481, 010
All other manufactures of iron not specified	....	2, 191, 059	....	2, 737, 588	....	3, 528, 941	....	3, 279, 704
Total	....	5, 770, 767	....	7, 805, 502	....	9, 406, 941	....	10, 636, 981
STEEL, AND MANUFACTURES OF:								
Ingots, bars, sheets, and wire .... Net tons	30	7, 364	9	3, 624	26	5, 481	343	29, 557
Cutlery	....	90, 064	....	31, 889	....	54, 409	....	50, 805
Edge-tools	....	532, 395	....	691, 415	....	862, 096	....	875, 538
Files and saws	....	13, 222	....	14, 536	....	16, 520	....	28, 173
Muskets, pistols, rifles, and sporting guns	....	5, 215, 128	....	1, 165, 424	....	1, 548, 227	....	3, 613, 430
All other manufactures of steel, not specified	....	207, 197	....	317, 735	....	236, 265	....	157, 323
Total	....	6, 065, 370	....	2, 224, 623	....	2, 722, 998	....	4, 754, 826
AGRICULTURAL IMPLEMENTS:								
Fanning-mills .... Number	36	1, 066	25	689	120	4, 330	48	1, 379
Horse-powers .... do	25	10, 410	26	7, 876	43	5, 726	95	47, 806
Mowers and reapers .... do	3, 509	377, 719	6, 636	765, 511	9, 882	1, 266, 761	17, 230	1, 886, 324
Plows and cultivators .... do	12, 999	169, 764	24, 781	320, 493	27, 008	368, 462	13, 109	169, 032
All other not specified	....	461, 861	....	670, 509	....	868, 703	....	1, 041, 952
Total	....	1, 020, 820	....	1, 765, 078	....	2, 513, 982	....	3, 146, 493
Scales and balances	....	107, 516	....	173, 423	....	187, 380	....	131, 996
Sewing-machines	....	2, 232, 697	....	2, 376, 873	....	1, 829, 675	....	1, 770, 951
Fire-engines and apparatus	....	9, 009	....	15, 118	....	26, 778	....	16, 485
Grand total	....	15, 206, 179	....	14, 360, 617	....	16, 687, 754	....	20, 460, 732

CHAPTER IX.

JAPAN, CHINA, TURKESTAN, INDIA, NEW ZEALAND, AND AUSTRALIA.

THE IRON-ORES AND THE STEEL OF JAPAN; JAPANESE FURNACE; CHINESE EXHIBIT OF IRON-ORES AND IRON FROM THE MARINE ARSENAL AT FOUCHOW; NATIVE CASTINGS FROM TURKESTAN; IRON AND STEEL OF BRITISH INDIA; INDIAN COALS; NATIVE FURNACE AND METHODS OF PRODUCING IRON; WOOTZ OR INDIAN STEEL; BUTTONS AND FORGED INGOTS OF; DEPOSITS OF IRON-ORE; NEW ZEALAND; ILFRACOMBE IRON COMPANY'S STEEL BELL.

167. THE IRON-ORES AND THE STEEL OF JAPAN.—The Japanese, who have entered most intelligently into the true spirit of the exhibition, have brought with them the best collection of their minerals yet seen abroad. In this collection we find their iron-ores chiefly in the form of iron-sand from the beaches of the volcanic shores of Nipon and Yesso. Magnetic and limonite ores are not wanting, but the disintegrated sandy ore is most used, being better suited than the massive ores to their primitive methods of manufacture. Their fuel is charcoal, and it is piled, together with the ore, in small quadrangular furnaces about 20 feet high. The blast is thrown in at the side from double bellows, worked by hand, and when sufficient ore has been reduced to form a bloom an opening is made in the front of the furnace, and the mass is pulled out and forged by hand. After several reheatings and forgings, rough disks of iron are obtained, which are cut up by chisels into short strips or bars ready for sale. A series of such bars, ranging from one to two feet in length, are in the collection.

There is also a model of the furnace commonly used. It has a square base and a pyramidal shaft, with an opening in front and two tuyère-holes on opposite sides. The model is one-twentieth of the size of the furnace, and from this the dimensions which follow are taken: Base, 10 feet square; height, 5 feet 10 inches; stack, 25 feet high. It appears to be like the old German oven or "stuhl" furnace, in which blooms only were made and pig-iron was an accidental product. The bottom or hearth is filled with charcoal and ashes, then the stack is similarly lined. A square opening is left in the back for charging the ore and fuel.

About the year 1860 an attempt was made to work the sand-ore of Yesso in a high blast-furnace, built after a European model, by Takeda, a talented Japanese engineer, but it was abandoned after an inspection and report to the government by the writer and Mr. Pumpelly. Since

then, near Yamukshinai, on Volcano Bay, small furnaces have been erected for making blooms. The furnace is torn down in front upon the completion of the process for each charge. The bloom generally weighs about one-third as much as the charge.*

Magnetic iron-ore of good quality exists in Nambu, at the northern end of Nipon, and has been successfully worked by Mr. Ohosima.

In addition to the bar-iron a great many samples of steel were shown. The steel is peculiar, and the precise method of its manufacture is not known. It is in irregular, spongy, or cellular masses, looking like slag or some meteorites. Although sufficiently brittle to be broken up into fragments, as desired by purchasers, it is malleable, and may be wrought into bars. The quality is excellent. Some of these specimens of steel were from the north part of Choisiu, or near it, and are called "mother of bar-steel;" others are from Hakoni, near Fusi-no-yama and from Oisiu.

168. CHINA.—The short and roughly-forged blooms and bars of iron sent from the interior of China show that methods of production similar to those of Japan prevail there. The work of developing the vast deposits, both of ore and of coal, which that country is known to possess has not yet commenced on a large scale under the direction of foreigners, but there is a large government establishment at the Fouchow marine arsenal, province of Foukien, which was represented in an interesting manner in the Chinese section. At this establishment the native iron product of Foukien and the surrounding country is worked up into merchantable bars and rods. The works are superintended by foreigners employed by the government, under a commission from Pekin, Prosper Gujal director, assisted by a committee of four mandarins of high rank. Some 2,500 Chinese are employed, and there are 130 officers and superintendents. The list includes 600 carpenters and marines, 800 workmen and apprentices, 500 laborers, 500 soldiers, 130 officers and superintendents.

This establishment sends a very interesting series of its products, consisting chiefly of forged bars and rods bent and broken in various ways to exhibit the quality, and all of which show a high degree of excellence. The greater part of the native iron is delivered to the works in the shape of small blooms weighing only four or five pounds. The ore, a fine black sand, like old-fashioned desk-sand, is a mixture of ordinary quartz river-sand with magnetic iron-sand, and is obtained by washing the river-sand, which sometimes does not yield over 1½ to 2 per cent. of ore. Five hundred pounds of ore yield, in their rude furnaces, about one hundred and fifty pounds of impure iron, which, by reheating and forging, is finally reduced to only eighty-three pounds. When these rough blooms and bars are combined and forged into commercial bars there is a further loss, but a very tough and fibrous iron is obtained. A very considerable quantity of old iron from condemned vessels, wrecks, and other sources is obtained at the sea-ports, and this is also worked

* Blakiston, Journey in Yesso, Jour. Geog. Soc., 1872, 136.

up at the arsenal. This establishment has been in successful operation since October, 1867, and appears to be giving not only important commercial results but to be educating a great number of the Chinese in western industrial methods.

169. CENTRAL ASIA—TURKESTAN.—There are interesting specimens of native castings from Turkestan, made, in part at least, according to the catalogue published by the imperial Russian commission, by melting up the broken and disused imported iron castings. The furnaces are very rude. They line the interior of a cast-iron pot with a layer of clay 1½ inches thick and fill it with charcoal, lighted at the bottom. A blast is thrown in from a tuyere just above the edge of the vessel and is directed downward toward the bottom. The charge of cast iron is piled upon the charcoal in pieces weighing from twenty to sixty pounds. Charcoal and more iron are added, as needed, until the pot is filled with molten iron. The slags and scoriæ being skimmed off, the iron is dipped out and the castings are made in moist sand. The blast is obtained from two leather sacks fitted with valves and worked by hand, so as to give a nearly continuous blast.

BRITISH INDIA.

170. The iron and steel products of British India are shown in the Indian collection, where we find a great variety of iron-ores and coals, one variety of the latter giving a very superior coke well adapted to the production of iron. Large blocks of magnetic, specular, and hematite ores bear witness to the wealth of India in the raw material, while the diminutive bars and hand-made blooms show that the industry of iron has not made progress generally beyond the primitive methods.

Through the labors of Dr. Oldham and his assistants of the geological survey of India, the great resources of that country in ores of iron have been made known. Superior magnetic ore exists in mountain masses near Salem and other places. Three separate attempts have been made to establish the manufacture of iron in India on a large scale, and considerable British capital, aided by the government, has been invested there, but up to this time without adequate success. Nothing has been done in this direction for several years, but renewed attention is being given to the subject, and Mr. Bauerman, a mining engineer, has been sent out from England to examine and report upon the mines, with a view to the erection of iron works on a large scale. One of the great difficulties want of proper fuel—has been removed by the discovery of a bed of good coking coal. The India coals belong not to the Carboniferous but to the Triassic series, and are allied, in their nature and age, to those of China.

The native production of iron is confined to the poorer classes. They make plow-points, spades, &c., but for wagon-tires they prefer foreign bars. The method of working was clearly shown by a very interesting model of a native iron furnace and its surroundings, showing the whole operation of smelting, forging, and reheating. The ore is broken up by

hand into small grains, and is charged into a low, box-like furnace, about four feet high and three feet and a half broad, with a large opening at the base in front. On each end there is a box four feet by two to hold ore and fuel.

The blast is supplied by bellows made of sheep or goat skin, worked by two women, and the bloom, when pulled out of the furnace, is chopped up by men with heavy hatchet-shaped hammers. The pieces are reheated and forged out. About twelve hours are required to each charge and the product is about one-third in weight of the ore charged. The ore is added at the top in layers with charcoal.

The reheating furnace is also very simple and primitive in its construction, being a box or oven about 6 feet long and 4 feet high, built over the blooms upon the ground. The blast is thrown in at the side.

According to Dr. Oldham, in the memoirs,* also on exhibition, the native furnaces range in height 3 to 5 feet, with an interior diameter of from 9 inches to 1 foot. They stand about 2 feet wide upon the ground, and taper upward, the back part more than the front. They are made of red clay, mixed with sand. The linings of clay last only three or four days. An excavation about a foot in depth is made for a hearth for the bloom. The opening in front is from 12 to 14 inches high, and is closed up during the operation. The blast is obtained by hand-power from skin-bellows, and the tuyeres are made of bamboo or sheet-iron covered with clay. A strong heat, varying in duration from two and one-half to four hours, is sufficient to give a bloom. An opening is then made in front, the bloom is drawn out, and while hot is cut into two parts by ax-like sledges. The usual charge is about eighteen pounds of ore, and the average product, with four men at each furnace, is three blooms in twelve hours. Such blooms are reheated several times, and hammered and worked into rude bars about one foot long and two inches wide. Wootz or Indian steel is prepared from such bars.† In 1860, a tax amounting to Rs. 1210–12–7 was raised on 775 such furnaces, while in 1859, 928 furnaces yielded Rs. 1451–1–7.

171. WOOTZ OR INDIAN STEEL.—Of equal, if not greater, interest, is a

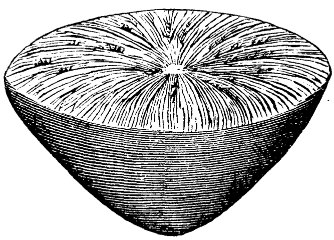


Fig. 65.

series of specimens of the famous "wootz" or Indian steel. It is crucible steel, made in small quantities, and from carefully-selected materials.

* Memoirs Geological Survey of India, iv, 155.

† See an account by Mr. Heath, Jour. Roy. Asiatic Soc., v.

The small clay crucibles, or pots, not over 4 inches high, are shown, together with the "button" as it remains in the crucible after cooling. The contents, after the fusion, are not poured out into a mold, but remain undisturbed in the bottom of the vessel. These buttons weigh only a few ounces, and are interesting from the peculiar crystallization which forms in the mass, and shows distinctly by fine raised radial lines on the surface.

BUTTON OF WOOTZ.—These buttons are malleable, and some are shown forged out into small square bars ready for market. Care is taken to leave traces of the crystalline markings at one end of the bar. They have every appearance of homogeneity, but a sample submitted to tests gives evidence of a different condition. The bar presented to me by the commissioners (No. 131 of Indian catalogue) has, at my request, been forged or drawn out at the Griswold Bessemer Steel Works, in Troy, and under the supervision of Mr. A. L. Holley, who reports it drew well at a low Bessemer heat, and when annealed broke off short, when cold, and would not bend at all on three trials. Fracture fine. "The ingot is apparently full of cinder, and is hence shaky and seamy." A piece drawn to a cold chisel, and tempered as usual, did not stand well. The experiments were carefully made, and the steel was not overheated. Evidently the ordinary treatment does not answer for this steel. The radial crystallization of the button is evidence of a difference of composition within the mass, one portion being apparently more fusible than the other. When drawn out this gives the effect of included "cinder."

172. IRON-ORES OF INDIA.—There are vast deposits of iron-ore in Northern India, near Kumarm and on Nerbudda River, and they are generally distributed over Northern India, but usually far from suitable fuel, even from forests. These ores are the magnetic and hematite, (specular.) Of the Salem iron region, "Kunjamullay" Oldham (iv, 157,) says they are close to railway lines, in gneissic rocks, forming a mountain. There are three principal beds of magnetic iron-ore, besides two others that crop to a limited extent. The two lower beds form conspicuous outcrops, and average say 50 feet in thickness, each. There are vast quantities of *débris* all about the mountain extending for one or two miles. The yield of the Porto Novo Company's furnace, at Beypoor, was about 55 per cent. of pig-iron, requiring $13\frac{1}{4}$ tons of coal for each ton of pig-iron obtained.

INDIA COAL.—There is only one good coking coal known in India at present. It is from Sanktoria colliery, Ranigunj coal-field, Lower Bengal, and gives from 74 to 76 per cent. of good coke, a large specimen of which, nearly two feet long, is shown with the other minerals of India. This field is considered to be the chief coal-field of India, and is probably Lower Oolite or Triassic in age. There are many different beds, and it is singular that some of them do not give a coking coal. The production (1873) is now nearly 484,642 tons annually, and it is increas-

ing. The mines are all worked with uncovered lamps. No Carboniferous coal is known in India, but it is supposed that there may be some in Burmah.

NEW ZEALAND.—The New Zealand court of the Exhibition contained a variety of specimens of magnetic, specular, and limonite ores, sent by the Colonial Museum. Among these the following may be noted: Magnetic iron-ore from Dun Mountain, Nelson, forming a vein 16 inches thick in serpentinous strata, also from Otago in mica schists. Specular ore (hematite) from the same localities, in regular veins in greenstone, (at Dun Mountain,) and in a 6-foot vein at Shotover, Otago. The black-iron sand from the beach at Taranaki was also represented, together with blooms and ingots, and bars of titanic steel and of workable steel. The ingot is a spongy, porous mass internally, but is compact at the surface and edges. The bar of crude titanic steel is 16 by $1\frac{1}{2}$ by $\frac{1}{2}$ inches.

The Ilfracombe Iron Company exhibited a bell of fine tone, cast from the steel made by the company.

CHAPTER X.

HYDRAULIC FORGING.

THE PARTS OF LOCOMOTIVES SHOWN BY HASWELL, AT VIENNA; ETCHED SURFACES, EXHIBITING THE "FLOW" OR STRUCTURE; THE PROCESS AT THE STATE RAILWAY WORKS; FORGING INGOTS, CAR-WHEELS, AND BOILER-HEADS; TRANSLATION OF HASWELL'S MEMOIR; THE PRESS; WROUGHT-IRON CROSS-HEADS; JOURNAL-BOXES; LINK MOTION SLIDING-BLOCKS; CYLINDER-HEADS; LOCOMOTIVE WHEELS AND CRANKS; ILLUSTRATIONS OF THE MANUFACTURE OF CAR-WHEELS UNDER THE PRESS.

174. The Austrian section contains examples of successful forging of intricate objects of large size in iron and steel, by Mr. Haswell, engineer of the Imperial State Railway Works, at Vienna. The objects shown are chiefly axle-box frames, cross-heads for locomotive pistons, link-bars, &c., and have been sliced longitudinally and then etched with acid so as to develop the grain or fiber and show its flow in the mold and general conformity to the shape of the object.

175. This method of forging, known as "Haswell's system," has been carried by him to a great degree of perfection, and is used in Vienna with great economy, while it gives results superior to those obtained by the ordinary methods. It consists essentially in forcing or pressing iron or steel, while at a welding heat, into suitable molds by means of the hydraulic press, carrying a follower or "stamp" upon the end of the piston. Both the mold and the stamp are used cold. Ingots or bars may be similarly forged or drawn down without a mold upon an anvil, without giving any blow or shock, as there is of necessity when heavy steam-hammers are used.

By the courtesy of Mr. Haswell I was admitted to the works, and shown the operation of the two powerful hydraulic presses upon both ingots and parts of locomotives.

The small press with an 18-inch piston gives 600 tons pressure, and the large press with a piston 24 inches in diameter gives 1,200 tons pressure. The pressure in the pumps is 600 atmospheres.

A soft Bessemer-steel ingot, weighing 2,030 pounds, was forged under the large press, and yielded noiselessly to the pressure as if it had been putty or soft cheese. As the piston-head descends, the metal is forced each way, and the pressure visibly extends to the very center of the mass, as shown by the movements of the lines of scale at the sides. The ends of the ingot are bulged out at the center, and not drawn over at the surface, as is often the case with hammer-forging, which, compared with hydraulic-press forging, seems very superficial. Under the

press, the whole mass of the ingot is affected. One great advantage of this method is the avoidance of great shocks, attendant upon the use of ponderous steam-hammers.

176. In forging intricate pieces, the molds are so made that they can be taken apart, and are held during the forging by strong bands. The follower, or stamp, is made of cast iron. The inside of the mold is oiled with old grease from railway-boxes. A lump of white-hot steel of the proper weight is thrown in; the stamp descends upon it and forces the metal into every recess and angle of the mold. Any excess of metal rises at the sides of the stamp, and is cut off when cold. Such forgings are alike in size and weight, and, of course, require much less trimming and fitting to bring them into shape for finishing. Care is required, of course, to get the right quantity of metal, to avoid a deficiency or an excess.

The method is successfully applied to the manufacture of car-wheels, the spokes and parts of the hub being forged in one piece, together with the crank-pin. Boiler-heads are made under the press in two heats. They are forced through a ring, and come out very true and perfect in form.

177. The importance of this method of manufacture to the industries of the United States justifies more than this brief notice, and as Mr. Haswell favored me with an illustrated copy of his descriptive *brochure* published in German in Vienna, I have had it translated and abridged for this report, and append it.*

MANUFACTURE OF PARTS OF LOCOMOTIVES BY PRESSURE.

By ROBERT LANE HASWELL.

[Translation.]

Forging by the action of Haswell's patent hydraulic-press, which was for the first time attempted in the machine-shops of the Austrian States Railroad Company, in 1861, has since been so materially improved, that at the present time there are but few parts of a locomotive which cannot be made by this method.

It may be said that this process is essentially identical with the common process of swaging with the steam-hammer, but to the close observer it is evident that Haswell's system greatly excels, since the pieces made by it are much more perfectly shaped, and by it it is possible to press out such pieces or parts which could not be hammered out with the swage-hammer; and further, this process is much more economical; renders it possible to produce those parts of a locomotive which hitherto have been made of two or more pieces in one piece; and lastly, there is a great saving of time and therefore of money.

* Fabrication von Locomotiv-Bestandtheilen durch Pressen system Haswell. Von Robert Lane Haswell. Mit 5 Tafeln. Wien, 1873. (Separat-Abdruck aus der Zeitschrift des österreichischen Ingenieur- und Architekten-Vereines, XII. u. XV. Heft. 1872.)

Some pieces which were made by this process at the works of the States Railroad Company, and which were exhibited at Paris in 1867, were so complete that they were taken for cast iron by French and English engineers, and it is a thing of great importance that a great many complicated pieces can be made by this process at the same cost as castings.

The quality of the work produced by this process, we may say, is of the very best, in consequence of the immense pressure brought to bear upon the material, and the process is particularly valuable for making articles out of Bessemer steel, since a steady pressure is much better adapted to this material than hammering. The many experiments which have been made have been so successful that we are justified in making the assertion that very soon no other process of forging will be employed. The most profitable application of this process is, without doubt, found in the manufacture of the more complicated forms. Borsig and Schwartzkopff, at Berlin, have two patent Haswell presses, one of 24,000 cwt., and another of 60,000 cwt. At Niederbronn, a press of 24,000 cwt. is building, and in England two are now in operation.

Every one who has anything to do with the building of locomotives knows how difficult it is, how long it takes, and what great expense is involved; therefore, convinced of the immense advantage of this method, I have decided to describe in detail the exact processes which are employed in the Imperial States Railway Locomotive shops, under the special direction of the patentee, Mr. John Haswell, hoping thereby to show to others the advantage, and to hasten the introduction of a system of forging which is not so commonly understood as it deserves to be.

178. THE HYDRAULIC PRESS.—The press used in the manufacture of the pieces here treated of has a power of 15,000 cwt., and a stroke of 20 inches. It is easy to see that such an apparatus is cheaper than a steam-hammer, since no such heavy foundations are required; and it is therefore more suitable for small establishments.

179. WROUGHT-IRON CROSS-HEADS.—In the manufacture, under the press, of locomotive cross-heads, the masses of iron to be pressed out are made in the usual manner by forging together refuse pieces of scrap and sheet iron. The weight of a bloom to make six cross-heads is 13 cwt. These blooms are hammered out, under a steam-hammer of 80 cwt., to a length of about 7 feet, a breadth of 11 inches, and a thickness of 7 inches. The bloom is then cut into six equal parts, and the pieces cut down till they weigh about 190 or 195 pounds each, and will easily go into the mold.

The pieces are placed in a common heating-furnace while still warm. The pressing is done at a single stroke, in the cast-iron mold placed upon the bed of the press. See Fig. 111.

The mold, as shown in the figure, consists of two parts, the upper and lower, *a* and *b*, which are inclosed in the wrought-iron blocks *d*. The

form of the cross-head is impressed into the upper part, and in the lower part, *b*, the form of the rest of the cross-head is made by the conical side pieces *c c*. These pieces are so made as to permit of their removal from the mold with the cross-head. The disk *f* determines the height of the shoulder for the piston-rod, and can be made thicker or thinner as desired. The disk *f*, also the side pieces *c c*, are put into the lower mold from above before the parts *a* and *b* are put together. G is the die which is fastened to the head of the press, and which closes up the mold at *h h* as far as the canals *p p*, (which must be kept open for

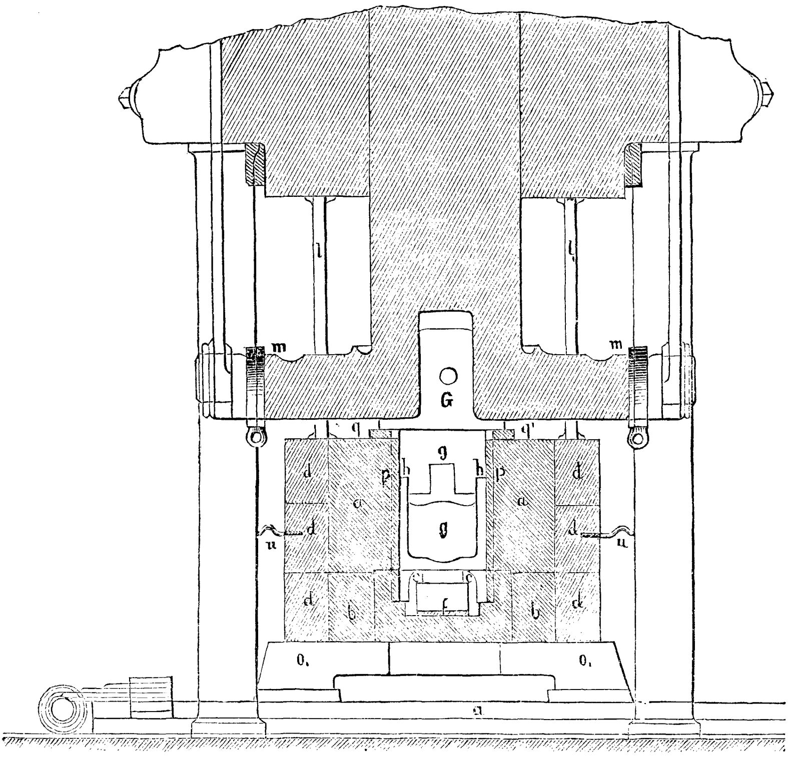


FIG. —Haswell's press, vertical section.

the exit of the air,) where it meets the prolonged side of the cross-head. The die G consists of two parts, *g g*, of which the upper part is made of cast iron, but the lower part must be made of cast steel, on account of its rapid destruction by burning off. The two bed plates, *q q*, limit the stroke of the press, and consequently the thickness and height of the cross-head. The mold rests upon a bed-plate, *o o*, (upon the height of which depends the length of stroke of the press,) and this bed-plate is placed upon a slide to permit of its being moved to the right or to the left from under the press. After the mold has been placed in the right position beneath the die, the props are adjusted to keep it in its proper

place during the operation of pressing and the inside is greased to facilitate the removal of the pressed piece.

The iron to be pressed must be at a strong welding heat when placed in the mold, and one single pressure then produces the cross-head. To take the finished cross-head from the mold, there are on the outside of the upper part two strong iron hooks, *u u*, by which it is fastened to the head of the press at *m m* with chains after the removal of the props. The side pieces *c c*, as shown in Fig. 112, start from the lower mold

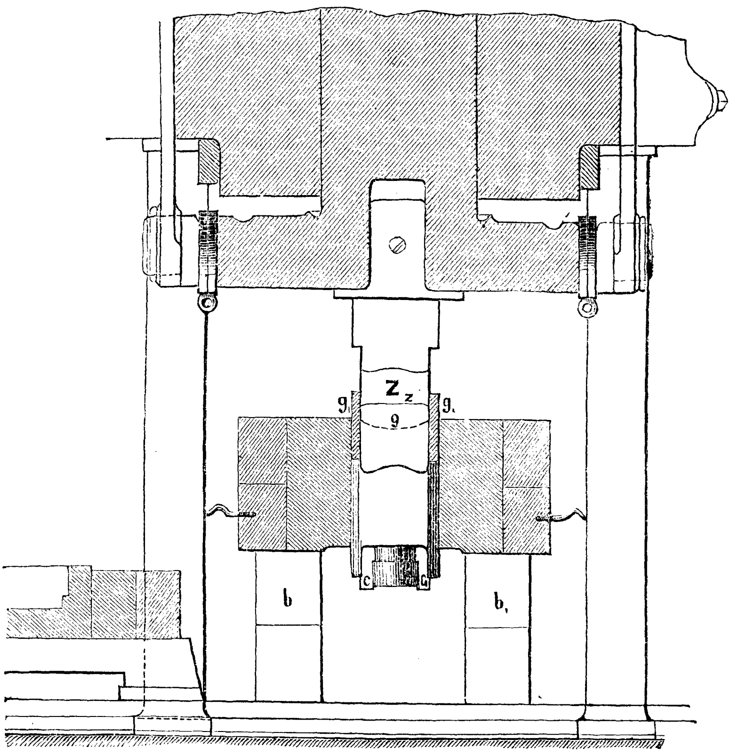


FIG. 112.—Haswell's press.

when the upper mold is drawn up, and are separated from the cross-head by a gentle stroke of the hammer. The lower mold is then removed from beneath the press by means of the fore-mentioned slide, (see Fig. 111,) and the upper mold put upon the foundation frame *b b*, which comes to stand in place of the former mold. The chains are now removed, the die G raised out of the mold as shown in figure 112; the pieces *g g*, which fit in the mold on the side of the die at Z, are placed in position against the top of the cross-head, and then, by a gentle pressure, the finished cross-head is forced out of the mold.

General remarks.—In the manufacture of cross-heads, bed-plates, journal-boxes, and all such parts as must be made in a closed space, the

weight of the piece which is to be pressed must be exact, as this is the most certain way to insure the right dimensions. The piece must moreover have but little play-room in the mold, as the process of pressing is very rapid, and the product might be uneven if permitted to move during the pressing. Immediately before pressing it is a good rule to throw in a few handfulls of hard coal-dust upon the white hot piece in the mold. This produces gas, which explodes on raising the die, and thereby tends to loosen the pressed piece in the mold.

Two furnaces, one for the hammer and one for the press, will produce from 25 to 30 cross-heads in ten hours.

The cost of cross-heads made by this process is about ten florins per hundred-weight.

180. WROUGHT-IRON JOURNAL-BOXES.—In the manufacture of journal boxes of wrought iron, the forging of the blooms, made in the same manner as in the previous case, is done under the steam-hammer. A bloom of the weight requisite for four journal-boxes (450 pounds) is hammered out to a length of 3 feet 4 inches, a width of 9½ inches, and thickness of 5 inches. The bloom is cut into four pieces, and each piece planed down to a weight of 107 pounds, and, while still warm, are put into the heating-furnace. Commonly two furnaces are employed, one for the hammer and one for the press. The mold is of the same general character as the one for cross-heads; the side pieces *c c* in this case being made so as to make the grease-boxes, and other changes being made to suit the case. The manipulation is also the same. The journals are taken out by raising the upper mold, removing the lower, and pressing them out as before, with the same precautions.

The great advantage of this process is that, under the great pressure which is produced, the iron enters all the parts of the mold, and a grain is made which follows the contour of the pieces, which are therefore much stronger.

In Figs. 107 and 108 is shown the grain of the iron in a journal-box and cross-head made in this manner. This grain is brought out so as to be easily seen by treating the sections of the pieces with acid for twenty-four hours, and shows how compact the iron of the pieces must be.

181. LINK-MOTION SLIDING-BLOCKS.—The manufacture of objects with annular openings is well illustrated in the production by pressure out of wrought iron of the sliding block which is attached to the link in locomotive engines.

Fig. 113 shows a sliding-block and the manner in which it is connected with the link. Fig. 114 is a front view of the same without the link. It is customary, for the sake of economy and convenience, to make two at once, and then to cut them in two. In Figs. 114 and 135, page 273, these complete double *sliding-blocks* are seen as they come from the press. The bearing points get in this way the theoretically correct grain, as is seen in Fig. 109. The piece is, moreover, so correctly fashioned as to leave little to do after the pressing.

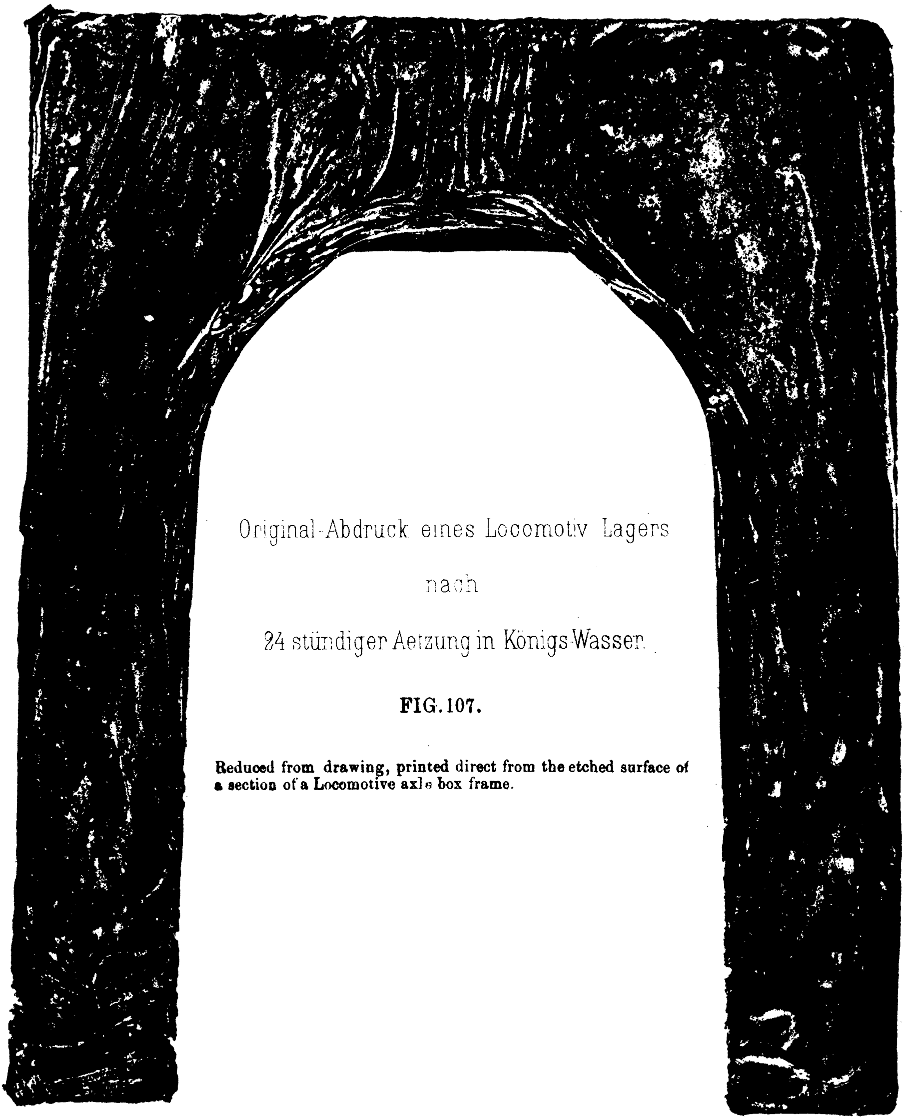
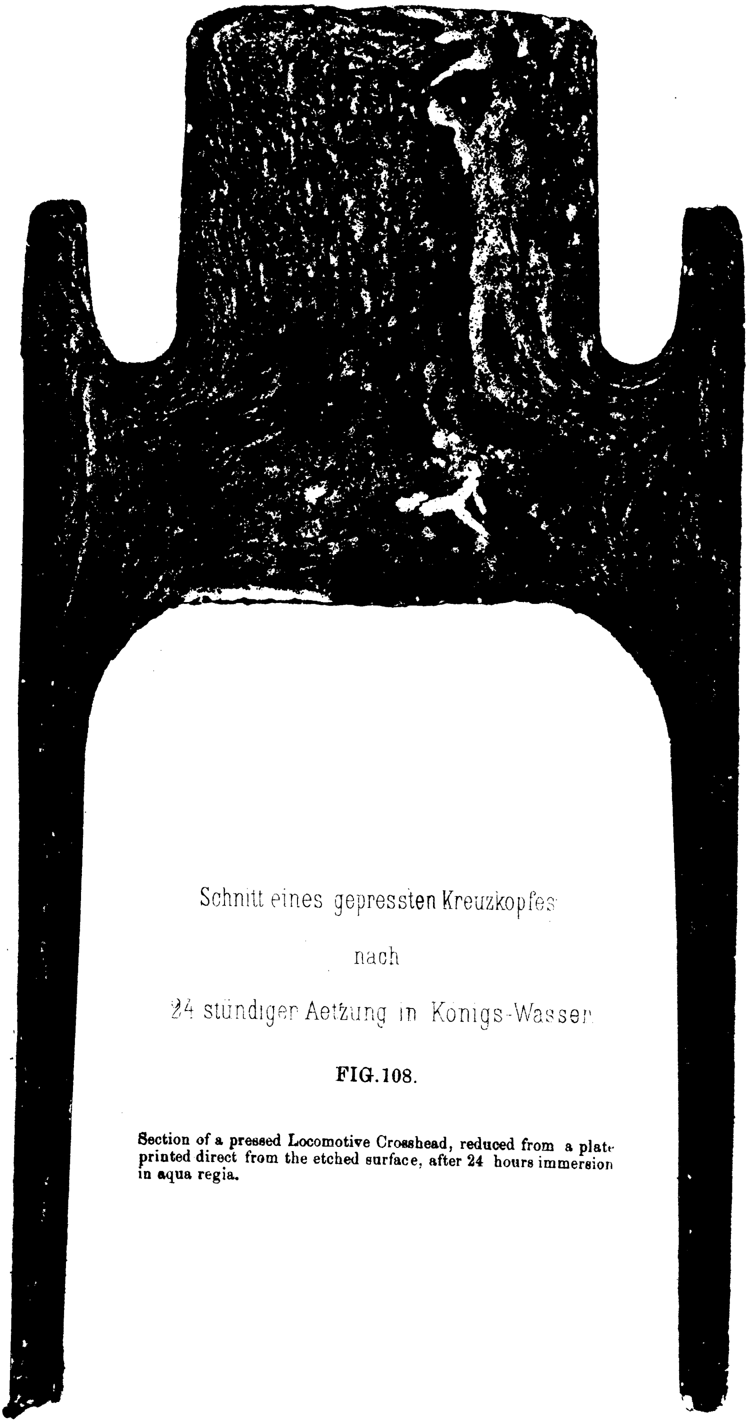


FIG. 107.

Reduced from drawing, printed direct from the etched surface of a section of a Locomotive axle box frame.



Schnitt eines gepressten Kreuzkopfes

nach

24 stündiger Aetzung in Königs-Wasser.

FIG. 108.

Section of a pressed Locomotive Crosshead, reduced from a plate printed direct from the etched surface, after 24 hours immersion in aqua regia.

SCHNITT EINES GEPRESSTEN DOPPELTEN SCHLEIFBOGEN-HANGEBACKENS

in Königs-Wasser geätzt.

FIG. 109

Section of a pressed link bar.

SCHNITT EINES GEPRESSTEN BALANCIER-FEDER BÜGELS

in Königs-Wasser geätzt.

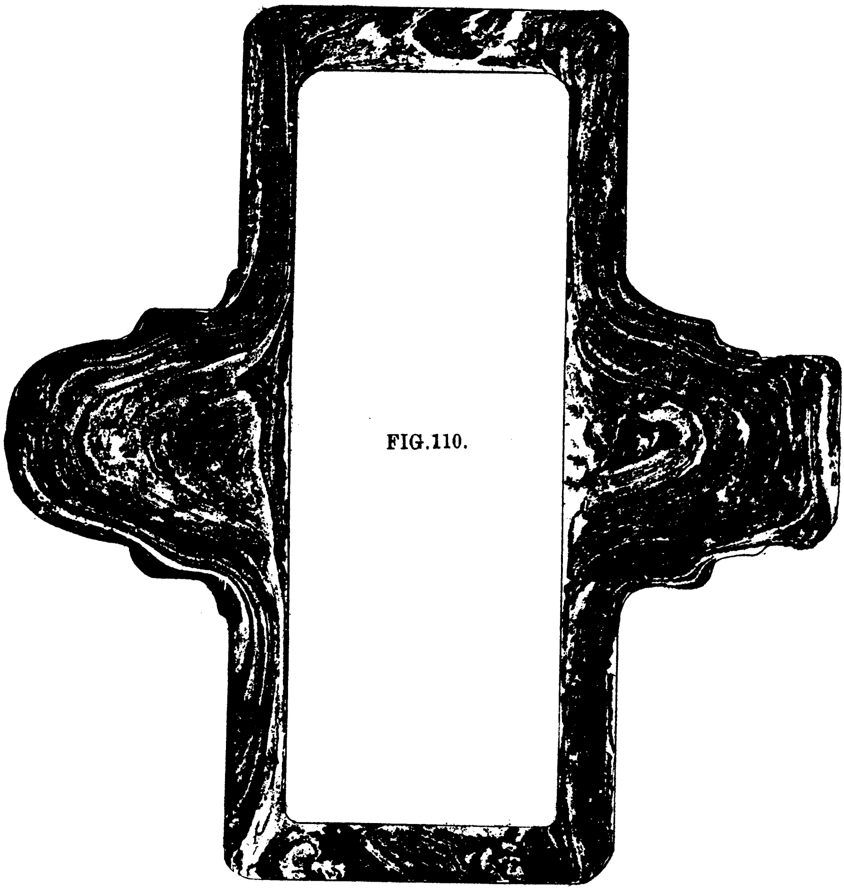


FIG.110.

Method of manufacture.—The bloom is composed of about 525 pounds of scrap-iron, which, as before, is hammered out, cut into four pieces, and heated in the heating-furnace.

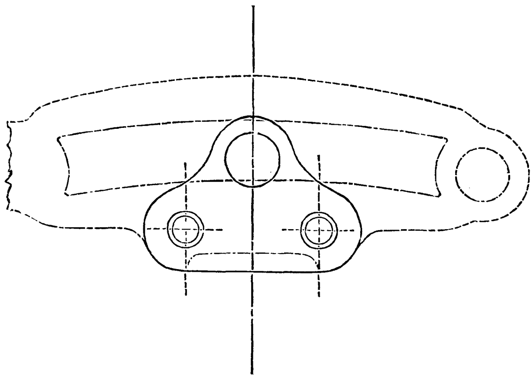


FIG. 113.—Sliding-block and link.

In Fig. 115 a view of the mold is given in its position after the pressing, but before the punching. It consists of the upper part A, (Figs. 115 and 116,) which rests upon the lower part B at the point *d;* of the side-pieces *u u* and *f*, which give shape to the *sliding-block;* and, lastly, of

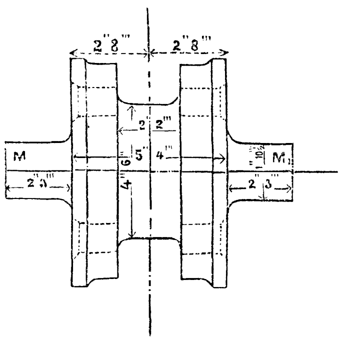


FIG. 114.—Front of sliding-block.

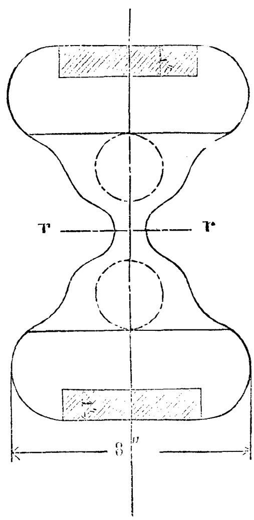


FIG. 114*a*.—Double sliding-blocks.

the die C, (Fig. 115.) The side-pieces *f* and *u u* are placed in the lower mold before the upper one is placed upon it. The side-piece *f* is held in position by the prop or wedge *n*, (Fig. 115.) This piece serves in the shaping of the piece, but is removed when the piece is punched.

After the mold is put together, as represented in Fig. 115, and the proper wedging and propping done, the piece of metal to be pressed is put in,

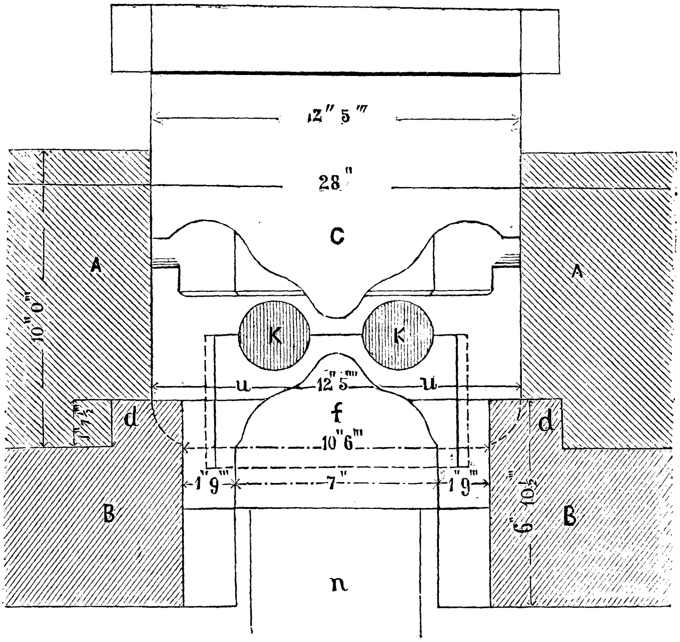


FIG. 115.—Mold for sliding-block.

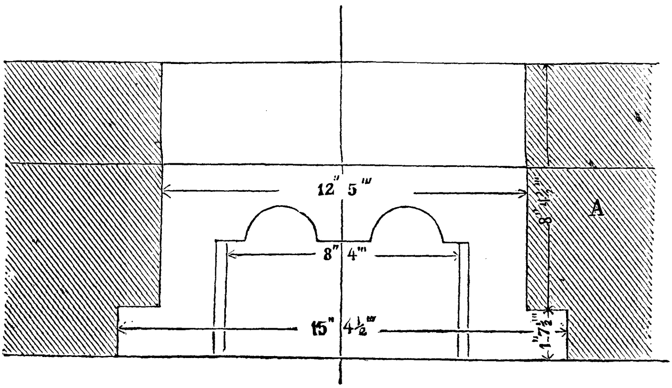


FIG. 116*a*.—Upper part of mold.

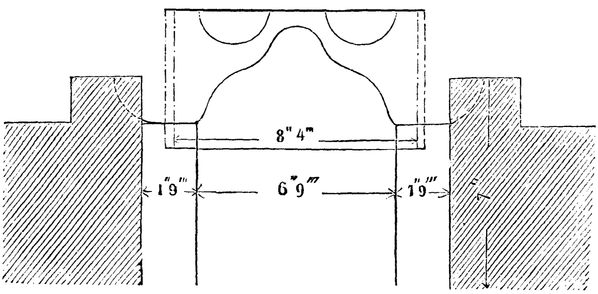


FIG. 116*b*.—Section on *b c* without *f*.

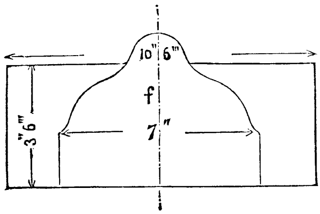


FIG. 116c.—Side view of *f*.

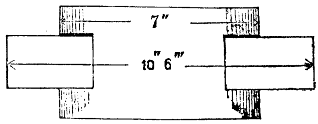


FIG. 116d.—Plan of *f*.

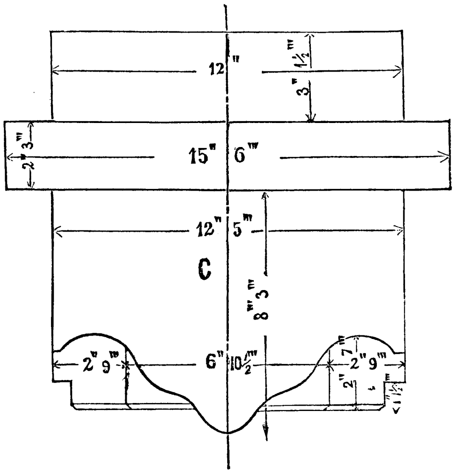


FIG. 116e.—Stamp or die.

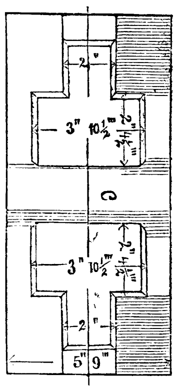


FIG. 116f.—Plan of the die.

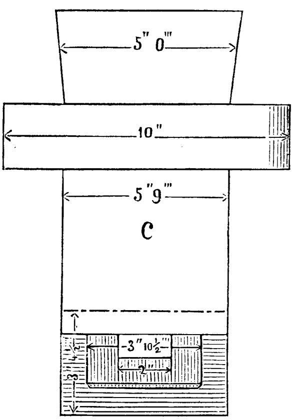


FIG. 116g.—Side view of the punch.

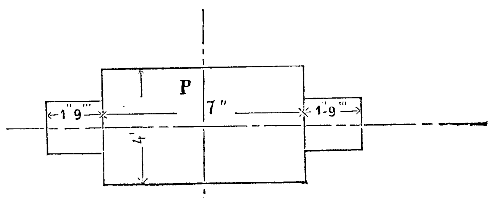


FIG. 117.—Top view of punch.

after being heated, as before mentioned. At a single stroke the piece is pressed. The die C is then raised, the side-piece *f* is removed by simply knocking away the prop *n*. The punch P (Figs. 117 and 118) is now placed in the impression already made by the die C, and pressed through. The wedges and props are then removed, the upper part elevated away from the lower, and then let down upon it again after laying some blocks between the two. The stamp Q (Fig. 119) is then placed upon the piece, and a gentle pressure frees it from the mold. The piece is then sawn in two and finished. By employing two fur-

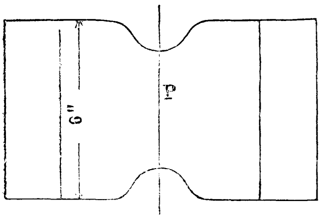


Fig. 118.—Side view.

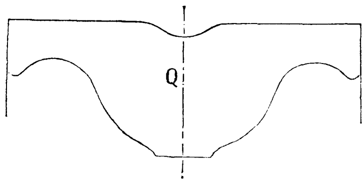


Fig. 119.—Stamp.

naces, from twenty to thirty of these sliding-blocks can be made in ten hours. Figures 134 to 138, page 273, further illustrate the process.

182. Cylinder-heads.—The manufacture of cylinder-heads of wrought iron by pressing is very similar to the forging of the same with steam-hammers, by swaging, but the difference in the expense of manufacture is very considerable.

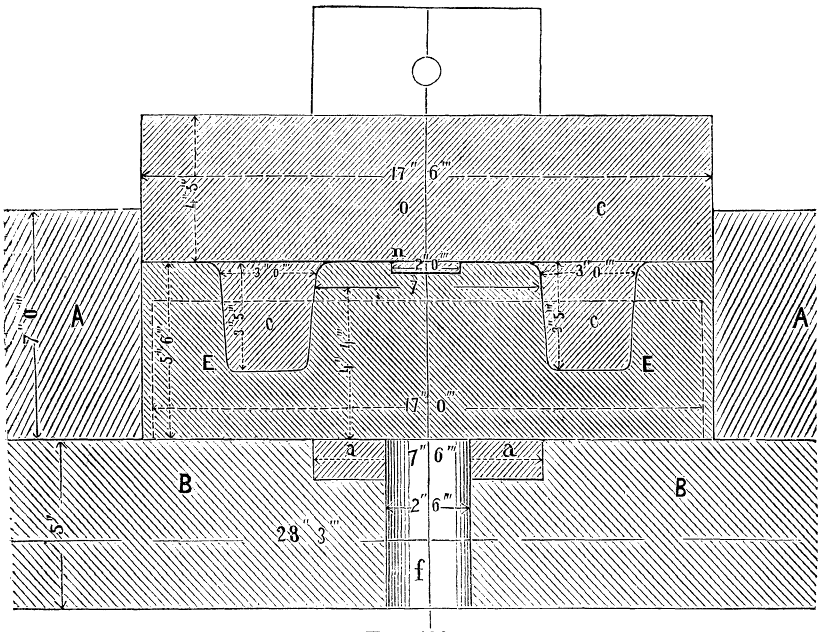


Fig. 120.

The bloom is made as before described, 260 pounds being required for one head. This piece is hammered under a steam-hammer of 80 hundred-

weight until it has a thickness of $4\frac{1}{3}$ inches and a diameter of 17 inches. Four pieces are placed in the heating-furnace at a time.

The cast-iron mold in which it is pressed is represented in Fig. 120. It consists of two parts, A and B, and the stamp C. Fig. 120 shows the mold as it appears when the cylinder-head is pressed, but not yet punched. E E represents the piece as placed in the mold before pressing. *A A* is a block of cast steel, which is put in the bottom of the mold so as to give a harder edge, which will better resist when the hole is subsequently punched.

After the cylinder-end is shaped, the die C is raised and the ring *n n*, Fig. 121, is laid on the surface of the piece to prevent it from splitting;

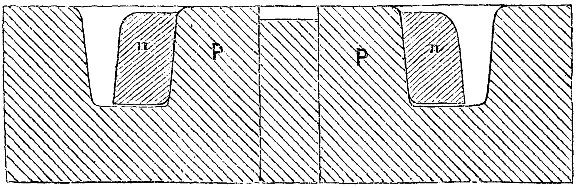


FIG. 121.

then the punch, of 2 inches in diameter, is placed in the impression made by the die and then pressed through.

The piece is separated from the mold as in the case last described.

From 20 to 25 of these pieces can be made in ten hours, with two furnaces, one for the hammer and one for the press. Another mold would, of course, double the production.

183. LOCOMOTIVE-WHEELS IN SOLID SEGMENTS BY PRESSURE.—The manufacture of the parts of wheels by the process of pressure enables the manufacturer to make segments with two or three spokes; and this process, in point of economy, strength, and beauty of product, has great advantages over the ordinary methods. A wheel with ten spokes, when made by the common methods, consists of twelve pieces; but when made by this process it is composed of but four pieces. We will give here only a description of the manufacture of the most complicated part of

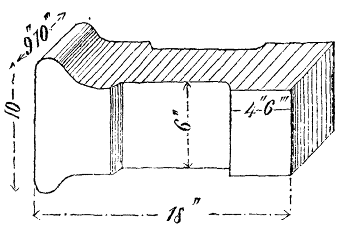


FIG. 122.

the wheel; that is the part with the crank-pin, as the other parts are made by a simpler repetition of the same process.

The manufacture of the segment of a wheel from wrought iron.—The bloom is made in the ordinary way, from scrap-iron, and has a weight of 250 pounds.

The bloom is forced under a steam-hammer (60 cwt.) into a parallelopipedon 16 inches long, 11 inches high, and 7 inches wide. While still warm it is put into the heating-furnace, and when very hot, is forged with the steam-hammer into the form shown in Fig. 122. The piece is then replaced in the heating-furnace preparatory to pressing.

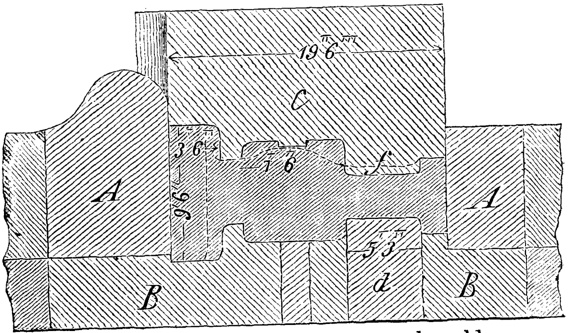


FIG. 123.—Vertical section through mold.

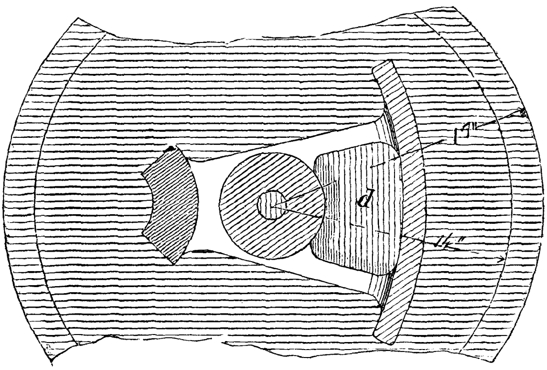


FIG. 124.—Lower mold B.

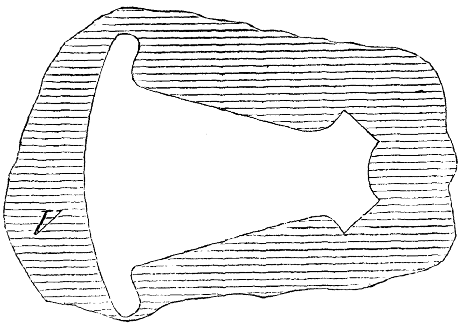


FIG. 125.—Mold A.

The piece is pressed in the cast-iron mold, (Figs. 123–125.) This consists of the upper mold A, the lower mold B, and the die C.

The punch *d*, which is seen in the lower mold, is kept in position by a brace. The outline of the die *C* is like that of the bottom of the mold, but with the addition of the shoulder *f*, which makes an impres-

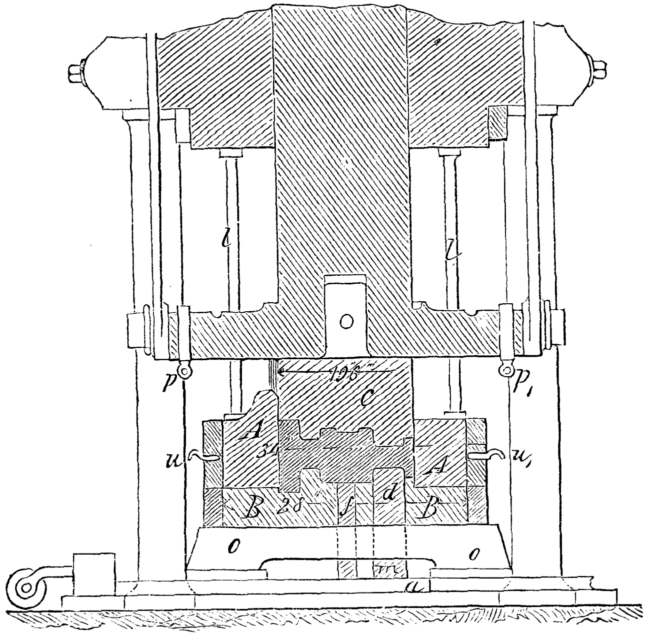


FIG. 126.—Wheel-segment in press.

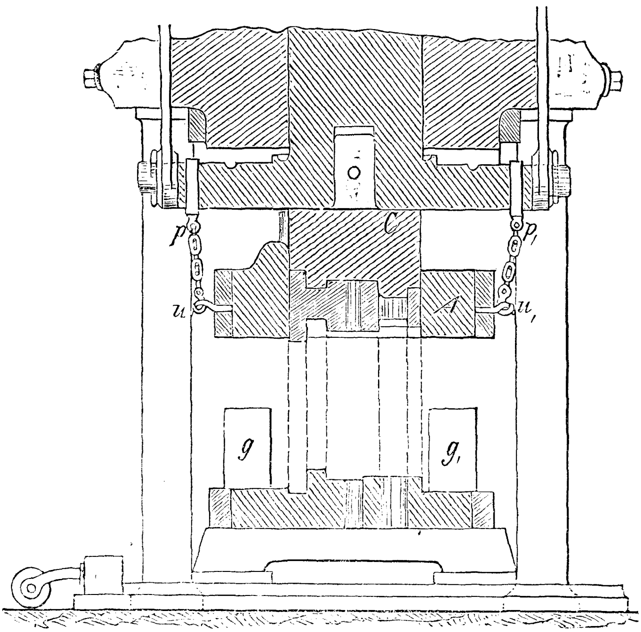


FIG. 127.—Vertical section through press and mold.

sion to guide the subsequent perforation. The mold stands on a bed-plate, O, (Fig. 126,) on which it can slide either to the right or left as desired.

When the mold is fixed in the proper position, and the braces *ll* are fixed so as to hold it there, and the mold thoroughly greased to facilitate the removal of the form, the piece (Fig. 122) is placed in the mold, being from the heating-furnace at a strong welding-heat. Now follows quickly the action of the press, by which the piece is shaped as shown in Fig. 123. The die *c* is now raised, and a punch corresponding in shape to the piece *d* in the lower mold is placed upon the impression made at *f*. The piece *d* is then removed by knocking away the brace, and the piece is perforated, thus forming the spokes. By a similar process the

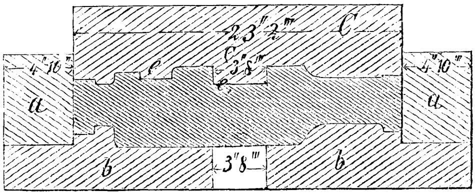


FIG. 128.—Section through mold.

hub is formed. The piece is removed from the mold by the same general process before described, by raising the upper part of the mold and gently forcing the piece out.

With two furnaces twenty-four pieces are produced in ten hours.

The expense is from 30 to 35 per cent. of the cost of forging the same under a steam-hammer.

The making of smaller wheels in one solid piece is, of course, only a repetition of the process of making segments. The whole wheel is first pressed and the spokes indented, and the interspaces afterward punched out. It may appear that there is a great waste of material in the process of pressing; but it will not be forgotten that every scrap is again used, and therefore no objection of this kind can be urged against this very important process. Figs. 128–130, inclusive, further illustrate this process.

184. LOCOMOTIVE-CRANKS OF WROUGHT IRON.—The bloom made in the same manner is forged into the shape represented in Fig. 131. It is then reheated in a furnace that will hold three such pieces of from 340 to 450 pounds each. The mold is shown in Fig. 132.

The pressing is quite simple. After the mold is braced, the shaped and heated piece is put in and receives the pressure. It will be easy to see that the iron is forced to flow into the die for the formation of the pin, as also the other parts of the mold. This flow necessarily creates a fiber which will run parallel with the pin, and will therefore be theoretically correct. The same will be the case with the body of the crank and the shoulder for the axle, since the crank is made considerably shorter than the mold. After pressing the crank a punch is placed on

the indentation at *g* and pressed through after removing the piece *f* from under the mold.

Twenty cranks can be produced in ten hours, at from 13 to 14 per cent. of the cost of cranks forged under the steam-hammer.

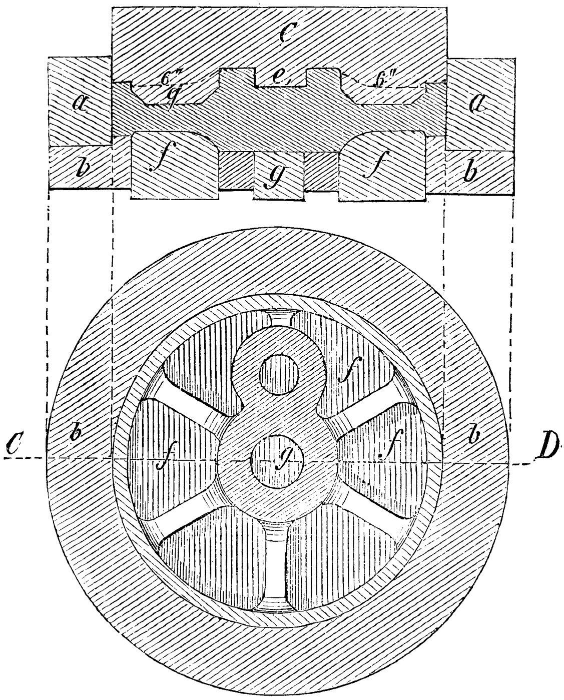


FIG. 129.—Lower die.

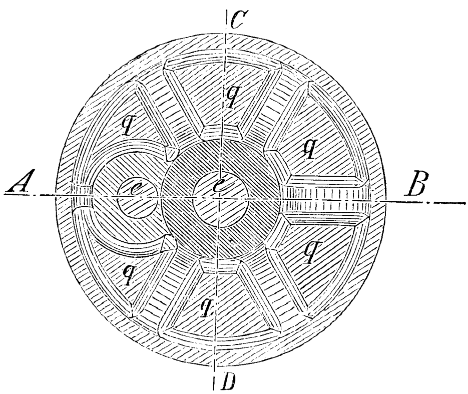


FIG. 130.—View of die from beneath.

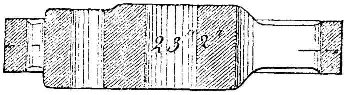


FIG. 131.—Locomotive-crank, first stage.

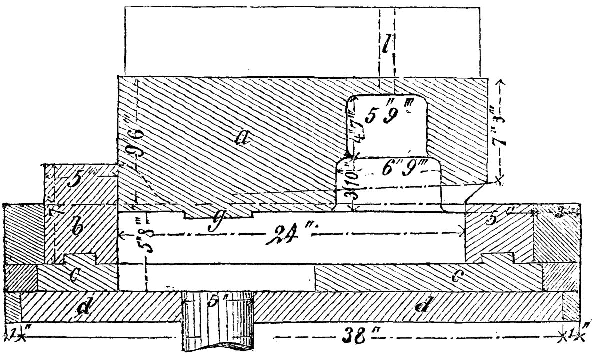


FIG. 132.—Vertical section through mold.

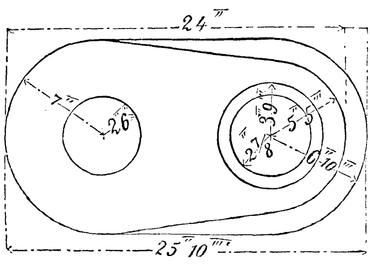


FIG. 133.—Crank.

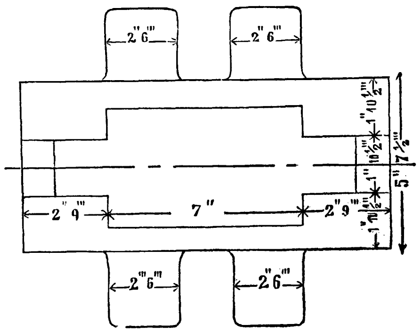


FIG. 134.—Mold for sliding-block plan.

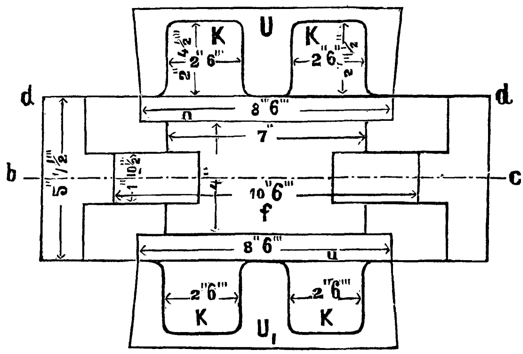


FIG. 135.—Plan of lower part of mold.

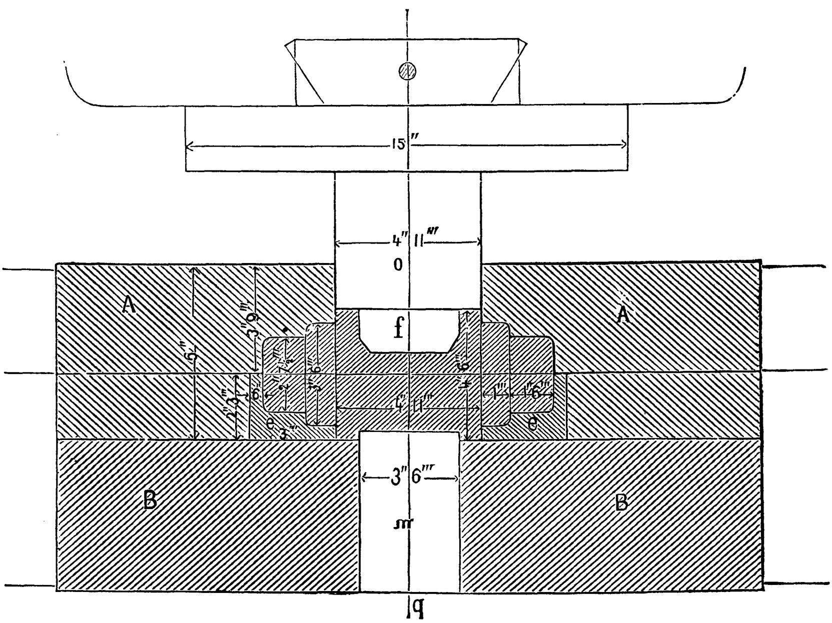


FIG. 136.—Section through mold.

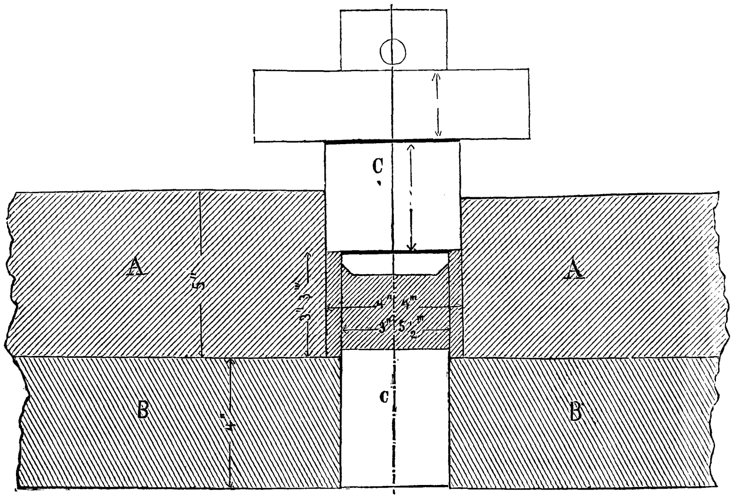


FIG. 137.—Section of mold and die.

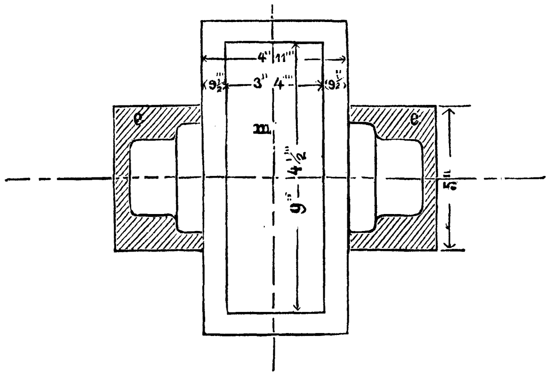


FIG. 138.—Plan showing part of mold.

CHAPTER XI.

IRON AS A MATERIAL FOR ART-WORK.

NUMEROUS EXAMPLES IN THE EXHIBITION OF THE USE OF IRON IN ARTISTIC MANUFACTURES; IRON CASTINGS; FORGED RAILINGS AND GATES; DAMASCENED WORK OF SPAIN; REPOUSSÉ WORK, ELCHO SHIELD; ENGLISH-MADE GATES AND RAILINGS; CAST-IRON REPRODUCTIONS OF ART-OBJECTS; ILSENDBURG FOUNDERY; MOLDING-SAND; QUALITY OF THE IRON USED; PROPER SELECTIONS AND MIXTURES.

185. This report would be deficient to a greater degree without at least a passing notice of the wealth of examples throughout the Exhibition of the use of iron in artistic manufactures. We find it in almost every section, either cast or wrought, in wire or in burnished steel. In the form of castings, we have the groups of life-size figures of men and animals, the exquisite bas-reliefs and reproductions of mediæval armor, and of the patiently executed *repoussé* work of gifted sculptors, sent by the Ilsenburg foundery, in the Harz.

For forgings we have only to turn to the splendid gilded gratings filling the spaces between the columns of the rotunda; to the entrance-gates of the jury pavilion; to the gates and railings inclosing the house and grounds of the British commission; to the examples of mediæval gates in the British section; to gates and floriated ornaments in the Belgian and Italian sections; and, finally, the railings of the Russian court.

The damascened work of Spain also challenges our admiration, particularly the objects shown by Placide Zuloaga, of Eibar, consisting of inlaid and carved iron, damascened caskets 6 inches long, 3 inches wide, and 4 inches high, for $250; buttons, shawl-pins, match-boxes, mirror-frames, platters, &c. The largest object is a shield of damascened iron, valued at $1,200. This industry appears to be reviving, and the artist has established agencies in London.

For *repoussé* work, the most notable example is found in the brilliant display made by the Elkingtons, of England. Here we find the famous Elcho volunteer challenge shield, presented by Lord Elcho to the volunteers of Great Britain, to be given over annually to the successful competitors at the great Wimbledon tournament. The shield is held in trust for this purpose, and was loaned to the Messrs. Elkington to exhibit by the trustees. This is the largest work in *repoussé* iron ever manufactured in England. It is 6 feet high, and in the mediæval style of art, from a design by F. Watts, R. A. Iron was selected as the material, because it does not tempt the cupidity of any one, and thus endanger its destruction. The workmanship, and not the material, con-

stitutes the value. The shield, which in general has the Norman form, has a hexagonal center-piece in the upper portion, bordered with a girdle, at and upon which is the inscription, "The Elcho Challenge Shield, A. D. 1862." A medallion portrait of Her Majesty the Queen is suspended from this, and occupies a central position. Above and within the space inclosed by the band there is a group representing Britannia. The crown and royal arms occupy the projecting points above and at the side. Upon the dexter side there is a representation of Queen Elizabeth reviewing her troops at Tilbury, and opposite to it Queen Victoria opening the volunteer competition at Wimbledon by firing the first shot. There are also representations of the battles of Bannockburn, 1314, and of Flodden Field, 1513, whilst at the foot two large-sized figures typify the close union now existing between the English and Scotch. A border of thistles and roses in high relief completes the idea.

186. WROUGHT GATES AND RAILINGS.—In the Italian section we mention particularly the wrought-iron gates and railings sent by Pasquale Franci, Rome, decorated with bunches of grapes, grape-vines, and leaves, even the tendrils all wrought with singular fidelity and beauty.

In the British section, aside from the Elkingtons' work, the principal exhibitor of art iron-work is the Coalbrook Dale Company, Shropshire, which makes a specialty of entrance-gates, fencing, verandas, balconies, railings, fountains, vases, &c. They exhibit two lengths of railing on either side of the north entrances to the British section, and a grand entrance in mediæval style, consisting of a pair of wrought-iron entrance-gates, two hand-gates, four pillars, and short lengths of railing to match, executed by the company from designs by B. J. Talbert, esq. The enrichments are of cast iron applied, and the twisted bars are produced by Tuddenham's patent process.

The gates, railings, gas, pillars, &c., inclosing the house of the royal British Commission, namely, the principal entrance of cast-sheet fence and gates, terminated by two gas-pillars; the two lengths improved cast palisade fence on either side; a length cast-sheet balcony-railing on east side; the west entrance to the building, of patent twisted angle-bar fence and gates; a length of the same fence, of various designs, on west and north sides; a length of bracket-railing on east side, within the grounds.

Various coats of arms and trophies in and about the house of the royal British Commission.

Various garden-chairs in grounds and park, namely, "Osmunda Regalis," "Water-Plant," "Mediæval," "Midsummer Night's Dream," "Nasturtium," "Horse Chestnut," "Medallion."

Various vases, &c., in grounds and park, namely, "Milton," "Night and Morning," "Classic," "Jardinière," various flower-stands in grounds and park.

CAST-IRON REPRODUCTIONS OF ART-OBJECTS.

187. ILSENBERG FOUNDERY.—The castings from the celebrated Ilsenberg Foundery are shown in great variety in a special installation

made of iron in one of the large buildings erected by Germany. Here are to be found reproductions of ancient armor, such as breast-plates, helmets, shields, sword-handles, &c., besides bas-reliefs, caskets, tazzas, and small objects for ornamental purposes. All of these objects are characterized by great sharpness of detail, smooth surfaces, and a higher degree of finish than is usually found in iron castings. The prices, also, are very moderate. An interesting history of the establishment and a technical discussion of the quality of the materials used, appears in "Engineering," and is appended.

COUNT STALBERG WERNIGERODE'S IRON-FOUNDERY AT ILSENBERG, HARZ.*—The Ilsenberg Iron-Works are among the oldest in Germany, and the iron-foundery there is most probably one of the earliest in the world. In ancient documents written in the fifteenth century pots, plates, balls, &c., cast at Ilsenburg, are mentioned; while cast-iron plates, which have been collected on the spot for some time past, afford additional evidence on this point. The director of the Ilsenberg Foundery, Oberhütten, Inspector Schott, has collected and arranged these plates in his official residence, and the collection possesses much interest, not only from an historical, but also from an artistic point of view. All these plates have served as stove-plates, and almost all are marked with a date, the earliest being that of the year 1509. The subjects on the plates are chiefly taken from the history of the Bible, and the ornaments consist of busts, tournaments, and allegorical pictures. The latter begin with the commencement of the seventeenth century. Some of the older plates are very beautiful, and the whole collection proves in the best possible manner the great perfection and the high position German art must have occupied in the sixteenth century, how it declined gradually during the thirty years' war, and how it finally died out utterly during the eighteenth century.

If the earlier time shows, however, the most originality—for instance, Judith in the tent of Holofernes, surrounded by guns and gabions—the design of the figures, dresses, &c., is, nevertheless, so satisfactory from an artistic point of view, that the pattern-makers of that time who had carved the models, some of which are still at the stores of the foundery, must have been men well skilled in their art, and must have attained a degree of perfection which has never been since reached. But the success did not rest with the skill shown in the pattern, the molder using the pattern evidently participated in it, otherwise such fine castings could not have been produced.

With the decline of skill in making the patterns the taste naturally became corrupted, and the molding less and less perfect, until eventually it lost all artistic value; even in the beginning of the present century the art of molding was still in a very primitive state. When the taste for artistic design began to revive, the hands, still rough and unskillful, were led to better and higher-class productions, which elevated the taste.

*From "Engineering," 1873.

When the appreciation of elegant forms shall have become general, then, and only then, we shall have in all branches of industry products equal to those of the sixteenth century, and the debased taste, now too common, will gradually disappear.

The necessity of extending art to all departments of industry occurred, nearly forty years ago, to Mr. Schott, who was at that time engaged on the Brunswick Works, the Carlshütte, and the Wilhelmshütte, both works being still famed for the excellency of their foundery productions. He is now, and has been for thirty-five years, the managing director of the Ilsenberg Foundery, and from the first he sought to cultivate art in the productions of the works. The results of his exertions in this direction are shown by the exhibits of castings of works of art in the German annexe for art and industry at the Vienna Exhibition.

The Ilsenberg Foundery exhibits at the Vienna Exhibition art-castings, which represent chiefly objects of the Roman period, of the Middle Ages, of the Renaissance period, and generally of such well-known works produced by master-hands as are most suitable for reproduction in iron. They are worthy of all praise for the clearness of the castings, and especially for beauty of form. They are not only suitable for decorative purposes, but they are very instructive.

It is unfortunately but too true that the want of appreciation has caused numerous works of art to be destroyed. Even in the first half of this century it has happened that ancient church-vessels have been sold by the authorities for the value of the metal for remelting. Such vandalism, however, is now no longer possible, and objects of art are sought for and carefully preserved. How much art-education has progressed in this direction has been fully proved by the many collections which have been made during the last few years. With refinement of taste increasing demands are made on precision and correctness of execution, and public taste has become greatly refined. Imitations and reproductions of antique works of art are no longer accepted as the simple copy of the outer forms, but an execution is demanded which should exactly represent the original in the smallest detail.

In consequence of the scrupulous exactness with which the old masters executed their work, and which did not admit of neglect even in the smallest and least important detail, great difficulties are met with in the reproduction of such works of art—difficulties which are especially great in iron castings on account of the impossibility of the parts being united by soldering. But notwithstanding these disadvantages the problem has been solved, and that in such a manner that iron castings may be substituted for electrotype productions, combining, as they do, greater strength with equal fineness, and, being cheaper, they should certainly be preferred. These are results which have been achieved through continued exertions with the view of cultivating pure art in the production of iron castings, and it is very desirable that these exertions should be continued by future iron-founders.

With regard to the process of production, it may be observed that the two main points upon which the casting of iron depends are the molding-sand and the metal. About three or four hundred years ago the conditions for preparing the sand required for casting upon the open hearth must have been known. It must even then have been recognized that the molding-sand should allow the penetration of the expanding gases, which are produced by the high temperature when the fluid metal is poured into the molds. Otherwise the fine castings already referred to could not have been produced. This condition of the molding-sand was far better understood in this remote period than at a later time, when an empiric preparation of the sand was considered to be sufficient, and by which means progress in the art of casting was necessarily hindered. When the question had to be decided as to what was to be done to improve the sand, especially for the production of sharp and fine castings, it is probable that a greater degree of fineness was tried. Unfortunately this condition of great fineness, which is decidedly necessary for sharpness in the castings, was accompanied by the disadvantage that the fluid metal, when poured into the mold, did not remain undisturbed, but destroyed the work of the molder. The problem was to find an explanation for these occurrences, and an acquaintance with the principles of the open hearth doubtless led to the conclusion that the want of penetrability, produced by the great fineness of the sand, caused this disadvantage. Nature rarely supplies a molding-sand which possesses both fineness and penetrability, and the general scarcity of such a sand, which induced many important iron-founderies to obtain it at great expense from distant places, naturally led to artificial productions being tried. We shall explain next the experiments made for producing an artificial molding-sand, and the results obtained.

188. MOLDING-SAND.—Of the various kinds of molding-sand at the disposal of the Ilsenberg Foundery, one is found in the neighborhood, in the diluvial formation, this sand consisting of a mixture of fat loam with coarse grains of quartz. It is used only for the molding of large pieces, and the molds made of it can be employed only after having been dried at a high temperature. A rather finer variety of this sand serves, when mixed with other sand, for larger class castings; but in this case, also, it is necessary that the prepared parts of the molds should be dried or heated in order that by the evaporation of the water there may be produced a contraction of the proportion of clay which the sand contains, and that thus there may be formed the minute channels which are necessary for the escape of the gases and steam generated at the high temperature of the fluid iron.

In the chalk formation, which fills the large and, in some places, deep basin adjoining the mountains of the Harzer district, there are found in the neighborhood of Ilsenberg, upon the chalky marl, strata of loam mixed more or less with grains of quartz of different degrees of fineness; the penetrability, and thus the utility of the molding-sand depending

upon this admixture. In a few exceptional places there is found a molding-sand that could almost be used in its natural state; the quantities thus obtained, however, are very small, and are not in proportion with the increasing demand of Ilsenberg Foundery. If, therefore, the artificial preparation of the molding-sand had not been successfully introduced, the necessary supply could only have been obtained from distant sources at great expense.

After having recognized the penetrability of the sand for steam and gas as the chief characteristic necessary, it became next an important matter to determine the signs of this required penetrability existing, and for this purpose the following process has been adopted: A known peculiarity of a sand which allows of a casting being made in it without the mold being artificially dried, is, that if the molder moistens the mold with water, the sand possesses the surprising quality of absorbing the water without altering the mold. The molder can thus, when working with the so-called green sand, employ water according to his requirments, in order to strengthen the sharp corners, edges, and ribs of the molds, for which purpose water may be dropped upon the latter by means of a brush. The water disappears, and is absorbed without doing any damage to the mold. This quality of the sand has been used at Ilsenberg in the following manner for determining the penetrability of the material. After various mixtures of sand have been prepared, and after it has been ascertained that sharp and distinct impressions can be taken with the materials, equal-sized balls or cubes are formed by compressing the sand in the hand, and that to such an extent that a slight further compression is just possible; this is easily done with a little practice, as this manipulation forms an important factor in ascertaining the quality of the sand for all molders, and determines the degree of moisture to be given to the molding-sand for casting in a green state. The balls of sand thus prepared, and made of uniform size, are then weighed, and water is next poured upon them as long as it is absorbed. When absorption no longer takes place, and the water appears to remain on the surface of the sand, the balls are weighed again. Supposing the different samples to be equally good, as far as the power of producing sharp impressions (as previously ascertained) is concerned, then that sample which is capable of absorbing the largest amount of water will offer the greatest facility for the escape of the gases and steam.*

It was in 1844 when, by the kind recommendation of the director of the Ecole des Mines at Paris, M. Le Play, the Professor Gaultié de Chaubri obtained for several professional men admission to some of the

*It should be mentioned here, that, in examining the sorts of sand, care has to be taken that the latter does not contain lime, which is often the case when the sand is found to lie on marl, and the greatest care should be taken in obtaining it. The burning of the lime, which takes place at the high temperature of the iron, forces the carbonic acid to escape, disturbs the fluid iron, and prevents the exactness and clearness of the casting. It is well to examine the amount of carbonic acid contained in the sand before using it, by pouring acid upon it.

founderies of Paris. Excellent molding-sand was to be found there, and the qualities which it possessed, necessary for the production of good castings, could be studied. The experience gained from the continued casting of bronze works, which could be applied to iron castings, and the great advantage possessed by these founderies of having to work only for specialties, and of not having, like other founderies, to change the class of work to be done every day, exercised a great influence upon the gradually improved preparation of the suitable sorts of molding-sand.

Even in Paris it was impossible to get from natural sources a sand that would fulfill all requirements, although remarkably good sand is easily obtained there. Only a few districts of England and Germany participate in this advantage, and the neighborhood of Halle-on-the-Saale and of Walkenrind, in the Harzer Mountains, should especially be mentioned in this respect. It thus became necessary, even in Paris, to prepare good and useful sand by artificial mixture. Four different sorts of sand, two of a reddish and two of a grayish-yellow color, were found to be applicable for casting in green sand. A variety of sand similar to the latter was found in exceptional instances in the neighborhood of Ilsenberg, but, as mentioned already, it could only be obtained in an insufficient quantity, and not of quite as good quality as that found at Paris. Comparing the Ilsenburg sand with the samples obtained from Paris, it was found that the former was deficient in the contents of fine grains of quartz, whence its penetrability was not the same as that of the Paris material.

The treatment above referred to of the sand consisting of a mixture of fat loam and coarse grains of quartz, the insufficient penetrability of which had to be increased by continued drying or roasting, had to be applied also to the fine sand, and it had to be ascertained whether the deficiency in the contents of grains of quartz could not be replaced by the roasting of a part of the denser sand, which was consequently exposed to such a high temperature that the yellowish-gray color was changed into red. The mixture of this roasted sand with the original yellow-grayish sand in its natural state, gave the desired result, and the roasted sand was found to be a perfect substitute for the grains of quartz in which the natural sand was deficient. In order to make, however, this artificial mixture equal to the natural sand, a careful treatment was necessary, and for this purpose stamping-mills and revolving drums of oval section, containing loose balls, were adopted for the powdering and mixing of the sand. These drums have a diameter of about 3½ feet and a length of not more than about four inches, while the speed of rotation is arranged in such a manner that the balls are not so acted upon by centrifugal force as to prevent them from remaining at the bottom of the drum, or they would not exercise the necessary pressure upon the sand, which is put into the drum through an opening at the side. In order to obtain the required

fineness of the sand, the passing of it through fine-meshed sieves becomes necessary, and for this purpose bolting-cloth made of sheep's wool, and known in Germany under the number 16, has been found best.

A fine molding-sand applicable for most castings in green sand was thus successfully produced, but the finer and better sorts of a reddish color, seen and found at Paris, which possess an extraordinarily high amount of penetrability, and which, moreover, allow of the cleanest and sharpest castings being made, were still wanted. It had been especially observed that the castings in this sand, which was even moistened to a great extent, remained unusually undisturbed, and it became, of course, a natural necessity to possess a molding-sand of equal quality.

At first an endeavor was made to discover such a sand in a naturally loose state, and it was thought that it might be found in the intermediate layers of the colored sandstone formation met with on the outskirts of the Harzer Mountains. All the sand, however, that could be found in a loose state in these strata contained too much clay for the required penetrability. Even after roasting it was found to be useless, because it had lost all its binding power, and attention was then directed to the solid sandstone, which, when ground, was expected to supply material of the necessary quality. The experiments made with these solid stones showed such a great penetrability that the best results could be obtained. The experiments with water pointed, fortunately, to a certain class of stones which had to be rejected for building purposes on account of their extraordinary hygroscopic qualities; these latter, however, justified great expectations for the molder—expectations which have now for many years been fulfilled. The mixture of the sand obtained from the stone, with the yellowish-gray sorts of sand mentioned above, has produced an exceedingly suitable molding-sand, the molder having it in his power, by adding more or less of this ground stone, to vary the quality of the material in accordance with the requirements of the work he has in hand.

The knowledge of the proper molding-sand required for a given pattern is the best proof of the ability of a molder, and such a knowledge can only be acquired by extended practice and correct advice, which latter, however, is unfortunately very often wanting in founderies producing inferior work. The importance of the correct preparation of the sand is in general little appreciated, and so long as no proper attention is paid to the requirements of a good molding-sand, and as long as there is wanting a correct understanding of the required penetrability in connection with a consistence of the material sufficient for the finest impressions, iron founderies will turn out works of art which could not be appreciated by eyes which have had opportunities of getting acquainted with more perfect productions.

From what has been said above, it will be found that the excellence of the molding-sand to be used does not depend so much upon the chemical composition, but rather upon the mechanical and correct mix-

ture of the argillaceous and siliceous components. If the chemical investigations made in Paris and London with the small parts of molding-sand that remained at those places on the castings exhibited by Ilsenberg had been ever so carefully performed, they could scarcely have led to the preparation of a suitable molding-sand, which depends simply upon the shape and size of the added grains of quartz, and the plastic qualities of clay.

In the course of years a special custom has often taken root in founderies, in consequence of which most extraordinary results are often produced. The practice acquired in the manipulations can go so far, for instance, that a sand possessing a very small amount of binding power, but a high degree of penetrability, as often found in nature, is used with the best results. The ability acquired to produce fine castings in a loose sand, which gives way to the smallest shaking, which possesses only so much consistency as is required to withstand the pouring in of the fluid metal, and which combines the advantage that the larger quantity of grains of quartz prevents a burning of the iron, and produces better castings, requiring only little cleaning, is a great gain, which saves many expenses incurred by the employment of a molding-sand of greater binding power.

189. QUALITY OF THE IRON.—Art-castings in iron require for their successful production a carefully chosen metal, one which must not only possess greater strength than is required for ordinary castings, but one which, by its density and fluidity in a molten state, is capable of reproducing minute forms with sharpness and exactness. In order to obtain definite information as to the conditions under which suitable iron is produced by the smelting process, the material has, at Ilsenberg, been subjected to careful examination, both when in the fluid state and during the progress of setting and cooling; and these investigations, which have been carried on for more than thirty years, have resulted in the discovery of the facts of which we propose now to speak—facts which are of high interest in themselves, and which appear to us worthy of the most careful attention of metallurgists. Some time ago the writer of the present article called attention to the appearances which cast iron assumes during the fluid state, these appearances varying according to the proportion of carbon which the material contains, and even as long ago as 1867 we spoke in this journal (in an article entitled "The Berlin Castings," a name formerly generally used for art-castings in iron, but now almost abandoned) respecting these appearances. The matter did not, however, at the time receive from scientific men the attention it undoubtedly deserves, and we therefore propose to return to the subject, and discuss it more fully.

According to the appearance of the new fracture when broken, pig-iron is, and has been for many years, both in this country and abroad, designated by certain numbers, the particular value attached to each number varying, however, in different localities. Speaking broadly,

No. 1 signifies a coarse-grained dark-gray iron; Nos. 2 and 3 are finer-grained and lighter grays; while beyond these come the "mottled" and "white" pigs. In many founderies in Germany the following scale is adopted: No. 1, largest-grained, highly graphitic, gray pig (*Gaares Eisen*;) No. 2, gray pig (*gaarflussiges Eisen*;) No. 3, mottled pig (*halbirtes Eisen*;) No. 4, strongly mottled pig (*stark halbirtes Eisen*;) No. 5, lamellar pig (*dünngrelles Eisen*;) No. 6, dead-white iron (*hochdunnes Eisen*;) and No. 7, white pig (*grelles Eisen.*) In this classification—which we shall adopt hereafter in speaking of the appearances of different classes of molten iron—Nos. 1 and 2 are varieties of gray iron, Nos. 3 and 4 of mottled iron, and Nos. 5, 6, and 7 of white iron.

If, now, an alteration in the working of the blast furnace or of the cupola shows that a change has taken place in the quality of the iron, or if it is desired to secure the success of a particular casting, the following observations may advantageously be made: Let a sample be taken from the iron available, and let it be cast in a semi-spherical mold, prepared as for an open-sand casting, but lined with finely-prepared sand, care being taken that the sand is neither too tightly nor too loosely pressed down. For making this simple casting, a small ladle and a straight-edge are carefully warmed, and the necessary quantity of iron is then tapped from the furnace or cupola into the ladle, the slag being removed with the heated straight-edge. When this has been done the iron is poured as quickly as possible into the mold, when the heated straight-edge is again passed over the iron. Experience has shown that when a furnace is working irregularly the various classes of iron above spoken of are sometimes to be found arranged one over the other, according to their specific gravities, and in procuring a sample, therefore, care should be taken to procure an average of the whole. The metal having been poured as above directed, the following observations should be made:

1. The color of the iron during the casting.
2. The movements which take place upon the surface of the metal immediately after pouring.
3. The state of the iron during and after its setting.

For the various classes of iron above enumerated these appearances will be as follows:

No. 1 iron.—This iron has during the casting a reddish-white color, and after running it remains unagitated, and has the appearance of a crystallized fat, while it presents a frothy surface covered with "kish."* Its fracture when cold is dark-gray, coarse-grained, glossy, and very soft, but when remelted it gets a finer structure, and becomes suitable for being recast in crucibles for the production of art-castings.

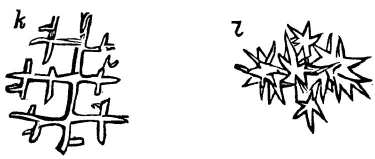
Another variety of this iron, during the pouring, has a lighter color than the variety of No. 1 previously mentioned, while, when cast, its surface is

* For the difference between graphite and "kish," see a paper contributed by M. Ledebur to the *Berg and Hüttenmanischen Zeitung*.

covered with a thick, dim skin, which during the experiment slowly separates in one direction in straight lines, showing at the fissures the bright metallic surface. After these movements have lasted some time, the dim skim again entirely unites, while the iron is seen to be still agitated, and commences to show small projections at those points where the division of the skin last occurred. After setting, the iron shows a slightly convex surface, which has a smooth glossy appearance, with here and there a sparkle of graphite.

This iron, when cold, has a dark-grey-glossy, fracture, the grains in the latter being the more strongly marked the greater the volume and strength of the casting. This class of material is well suited for the casting of fine works of art, as, when quickly poured, it fills the molds well and perfectly, possessing at the same time a great amount of softness. When less quickly poured, the separation of "kish" gives to the casting an objectionable appearance, similar to that of the first-mentioned variety after setting.

No. 2 iron.—This iron has, during the pouring, a dazzling-white color, while the dim skin which forms on the surface does not appear to be so thick as in the case of the class of iron last spoken of. As the iron runs from the ladle, a tearing-asunder of this skin and a display of a metallic glare below is observed, the surface at first splitting only in one direction, but fissures subsequently opening up in various directions, the following sketches, *k* and *l*, showing the chief figures formed. The figure *k* refers to a charcoal, and figure *l* to a coke, iron. These figures may often be traced even after the setting of the iron, they being then formed by projection on the surface. After the fissures on the surface have been drawn together again, the iron, which is still agitated beneath, evolves small bubbles of gas, which force their way to the surface, this being especially the case toward the middle of the mass.



Crystallization of iron.

With the exception of the points where projections mark the last fissures in the skin, the surface of this iron, when set, is dim, glossy, and smooth, and its appearance is similar to that of refined metal, this being the case even in the fracture, with the exception of a little lighter color and slightly denser structure. This iron is the best for art-castings, as the largest as well as the smallest articles may be safely cast from it, it giving clean and sharply-marked productions, which can be well worked on account of their but slight degree of hardness. If also the blast-furnace charges are good, and the varieties used in the cupola well chosen, iron of this class shows great flexibility and elasticity.

No. 3, or slightly-mottled iron.—This iron has, when poured, a light or white color, the skin being similar to that of the No. 1 iron, but thinner, while at the point where the flowing commences a stronger metallic luster appears on the broken surface. After the pouring has taken place, the iron at first, like that last mentioned, shows fissures in the skin extending in one direction only; but this merely lasts for a short time, a dividing of the lines then taking place, and cruciform fissures being formed for charcoal, and star-like fissures for coke iron.

This splitting up of the surface into fissures goes on very rapidly, new figures continually appearing only to disappear again and make room for others, the appearance being altogether a very interesting one, while the backward and forward movement in the material is remarkable. After this state of affairs has lasted some time the evolution of bubbles of gas commences, the bubbles being more numerous and being evolved with greater activity than in the cases formerly noted. During this period a great agitation of the metal occurs, this decreasing gradually until the iron is "dead," when it begins to set. The surface in this case is no longer rounded, but straight, and is covered with a number of small spheres, which show empty hollow spaces, and adhere very strongly to the surface, so that they cannot readily be removed.

The fracture of this iron shows a light color and slightly glossy surface, and is no longer strongly grained. The material is still suitable for art-castings, but the objects cast from it should not have thin places, as they could not be worked upon, and would require previous annealing. On account of its great density, however, this iron is well suited for castings which have to be bored or turned, and particularly for those on which polished surfaces have to be got up. The problem is to produce an iron of this kind with the peculiarity of not being inclined to chill; but this can be done by care in charging the furnaces.

No. 4, strongly-mottled iron.—If the iron is strongly mottled—approaching in character to No. 5—it shows, when poured, a brighter appearance and higher metallic luster than that last described. The fissures formed in the surface-skin are similar to those of No. 3, but the figures formed are smaller, and the changes take place more rapidly, so that a certain amount of practice is required to enable appearances to be fixed by the eye. The formation of the gas-bubbles also is more distinct, and their evolution commences at an earlier stage.

The setting of the iron takes place under conditions similar to those last described, but the surface becomes covered with numerous leaves covering larger or smaller concavities in the surface of the iron, according to whether the leaves have been formed by the combination of several bubbles, or by the adhesion of single ones. The surface is straight, and the fracture has a light, fine-grained appearance. This iron cannot be used for fine-art objects, but it may be employed for larger articles, which posses a certain degree of strength.

No. 5, or lamellar iron.—When poured, this iron (which is scarcely to

be regarded as a white pig) shows a light brilliant color, while the luster which accompanies the breaking of the skin is greater than in the varieties previously noted. After pouring, a to-and-fro movement of the fluid metal takes place, but this only lasts a short time, being followed by the formation of stellated figures, which change rapidly, and which are like those sketched above. In this metal the figures are smaller in size than those produced by the classes of iron already spoken of, while the bubbles of gas are more frequent, and of larger diameter. These bubbles unite to form the large leaves which, being hollow, cool more quickly than the mass of metal below, thus giving the surface the peculiar appearance of a red-hot mass of iron covered with dark spots, this being especially the case around the circumference, where the cooling takes place earlier. This appearance is not much liked in founderies for fine work, as it signifies an iron suitable for heavy castings only, but especially applicable to some parts of machinery. The fracture of this iron is lighter than that of the earlier numbers, and it shows fine white patches, and a very dense grain.

No. 6, *or " dead-white" iron.*—The conditions just described are to be found, also, to a great extent, in the case of "dead-white" iron; but the formation of the figures is in this case still more rapid, and the fluidity of the iron is of less duration. The size and quantity of the gas-bubbles are also considerably increased, as is also the appearance of the dark spots already referred to. The surface, too, when set, is no longer straight, but slightly concave, while, after the opening of the leaves produced by the bubbles of gas, deep holes are seen. The difference in the two classes of iron consists in the latter having not only deep, but also flat holes, the existence of these proving the iron to be of a harder class than the other. The fracture of this metal shows a mixture of white and gray iron, this variety marking the transition to white iron properly so called. If the proportion of grey and white is about equal, the metal is known on the Continent as "Forellen" iron. Such iron is no longer suitable for fine castings, but if produced by a well-selected charging of the furnace, it possesses a very close structure and great strength. This iron is especially suitable for casting large rolls, which gain in strength through their cooling very slowly, and which can be subsequently turned. It is also suitable for the production of chilled castings, of which samples are exhibited at Vienna by the Innerberger Gewerkschaft, of Styria.

No. 7, *white iron.*—The form of this iron in section when cold is concave. When poured, this iron has a white color, but this very soon changes to red, while the metallic luster is very strong. The splitting or opening up of the skin does not last long, but soon makes room for the formation of large gas-bubbles, which may be observed violently agitating the mass. These bubbles burst, and the discharge of gas takes place with such force that fine particles of burning iron are thrown out in all directions. The surface next begins to sink, and soon after a dark skin begins to spread like a shadow over the surface

of the still red-hot mass, from the circumference toward the center. Finally this skin becomes lighter and peels off, showing a number of the shallow cavities described above. The fracture of this iron is white, and the metal is too hard to allow of its being worked.

The characteristic appearances of the various sorts of iron depend upon and are intimately connected with the proportions of silicium, manganese, phosphorus, sulphur, &c., which the iron contains. If, for instance, in an otherwise normal state of the iron, the contents of sulphur in the latter is proportionately large, the so-called "Bräunen," with the leaving behind of flat holes, may be observed. The shape of the figures due to the fissures in the skin is also altered if an addition of zinc, copper, &c., is made, and, for instance, the addition of tin causes these figures to alter their shape entirely, and gives rise to beautiful formations. It is often surprising how, for similar reasons, the iron, which, at the beginning of the observations described in our former article, showed a distinct characteristic, alters in its appearance suddenly and unexpectedly.

The formation of distinct figures by the division of the surface skin was formerly attributed chiefly to the inclination of the iron towards crystallization, but a closer knowledge of the composition of the iron has shown that the generation of gas dependent on this composition, and accelerated and acting through the presence of the oxygen of the air mixed with the metal by the act of pouring out, must exercise an influence upon the formation; this generation of gas being proved by the bubbles that rise and escape.

The question now is, whether conclusions cannot be drawn beforehand from these observations respecting the composition of the iron, and whether a preliminary determination of the contents of sulphur, phosphorus, carbon, manganese, &c., cannot approximately be made. How important these observations would be for the industry of iron if, as has not so far been the case, they could be connected with chemical analysis, and how much more instructive would they be if microscopic investigations of the crystalline formation could be added. The latter investigations certainly deserve more thorough study than they have hitherto received, a neglect which can only be explained by the difficulty of the observations, the lens necessarily having to be placed close to the surface of the iron that is under examination, and it thus being impossible to obtain a large field of view, a few particles only being in the right focus.

Long and continued study and practical observation have made the present writer acquainted with the treatment of iron in the foundery, and he is thus in the position to state briefly a few rules which may be useful for determining the suitable sort of iron for special classes of art-castings. The following statements are therefore laid before the public, with the request of an indulgent and unprejudiced judgment.

In iron bars, which show after the setting hollow internal spaces, (such as must necessarily be produced in consequence of the setting growing from out to inside, if nothing is done for their prevention,)

there are to be found in these hollow spaces octahedral crystals more or less beautifully formed according to the degree of fluidity of the iron. Now, notwithstanding the exact resemblance of the fundamental shape of the crystal, it will be found, if the various samples of iron are compared with each other in this respect, that *one* difference may be observed, namely, the different proportions between longitudinal and cross axes of the crystals. The more beautifully the crystals are shaped, the more clearly is this difference of proportion observable. Very large formations of crystals are often to be seen in the more capacious cavities of large castings, but these are seldom of such pure and delicate forms as those to be found in smaller cavities. If they are completely formed they resemble small fir-trees, as octahedral needles at certain distances, forming also an octahedral-like space, and will be found to have arranged themselves around a central axis.

By the aid of a powerful lens a similar appearance is to be found in the surfaces of fractures of iron which are more minutely examined, whilst even a smaller magnifying power shows the triangular surfaces of the crystals and their proportionately different longitudinal axes.

The same class of crystals is to be found in all kinds of iron and steel, and the similarity is often so great that the assertion might almost be made that cast iron is nothing else but a compound of bar-iron crystals and graphite, and that the quality of the cast iron depends upon the proportion and character of the mixture of these components.

Such an opportunity as is at present given at the Vienna Exhibition for the study and comparison of various sorts of iron is very seldom offered, and never again perhaps will such a perfect series of samples of iron and steel from all parts of the world be found collected together as at present at Vienna. Examining now these various sorts of iron, it will be acknowledged that to produce a certain class of castings, the pig-iron forming the charges of the cupola or melting-furnace should be selected and examined with the same care as the ores for the charges of a blast-furnace; but while in the latter case the nature and quality of the ores to be used are thoroughly investigated before being fed into the furnace, the iron for the cupola is but too generally examined only slightly and superficially, and a microscopic examination, which would offer some reliable data, is seldom resorted to. Instead of this, however, the quality of the iron is estimated from the place of its production, and if the nature of a certain brand of iron, supplied by known iron-works, has once been ascertained, it is generally taken for granted that all further supplies from the same works will have the same qualities. Where, however, (as is generally the case,) the charges of the blast-furnace are not always the same, the iron produced should be chemically, or at least microscopically, examined before being used in the cupola for the production of castings of a given quality.

This matter, which is of such great importance, has hitherto been so little or so seldom cared for, that the present writer desires to direct especial attention to his own experimental observations, in the hope that

other professional men will also take some interest in the development of this important subject. The importance of this matter for the whole of the iron and steel industry will be distinctly seen in the diversity of the conditions of the various sorts of Bessemer pig after the changes in the different stages of the Bessemer process, and a comparison of the processes brought, at the Vienna Exhibition, before the public is highly interesting.

While, for instance, the gray Swedish Bessemer pig changes under the slightest treatment quickly at first into spiegeleisen, the Bessemer metal exhibited in the various stages of treatment by Ockhowo, Government Ekaterinoshau, (Russia,) shows, even in the higher stages of the Bessemer process, still some graphite. With respect to the foundery, the iron containing carbon in a fixed state cannot be cast well, (the appearance of the malleable cast iron should be considered,) nor does it allow of any working treatment, and is thus not so good as that (according to the opinion expressed above) consisting of a mixture of wrought-iron crystals and graphite; it is therefore of great importance for the foundery that a pig-iron should be used which has not the qualities of the Swedish iron, but that of the iron exhibited by Ockhowo.

It has to be considered that the iron, having become fluid in the higher temperatures of the ordinary cupola, has to pass in its descent through the current of air still saturated with oxygen, that it is subjected to an alteration similar to the fining process, and that it will become white and hard if the formation of graphite has not been reconstituted by the abundance of carbon. In connection with this matter we may mention the cupola-furnace invented by Herr Krigar, of Hanover, this furnace being constructed so that the molten iron is withdrawn from contact with the coke and blast, the hearth for receiving the iron being to one side of the furnace and not directly below the crucible as usual. When this furnace has been correctly put up, its use has always been attended with an economy of coke; but this is not its only advantage. A leading feature is the decrease of the danger of producing white and hard iron. Hence in a furnace on Krigar's system, a larger percentage of coke-iron may be added to charcoal-iron without producing a white metal than is possible under ordinary circumstances. In fact in Krigar's furnace a suitable metal for art-castings may be obtained by the use of coke-iron, although, of course, charcoal-iron is always to be preferred.

In support of the opinion that no iron having an inclination to get white should be applied for art-castings, we may refer to the fine iron castings exhibited by Rastorgonieff, of the Usines de Kischtim, near Perm, in the Ural, (Russia,) which have been produced by previously submitting the iron used for them to a trial in open sand-molds, when it was first determined that the iron would not get white, but would remain gray; if this was not the case it was not used.

It is further certainly erroneous to suppose that a large percentage of phosphorus, which tends to make iron become white, is especially advantageous for art-castings, and this opinion is only correct in so far

that the normal working of a blast-furnace using limonite ores produces an iron free from "kish" or iron froth, and which is of a very fluid nature, penetrating sharply into every form, although it is hard and possesses the necessary strength.

This quality and that of other sorts of iron corresponds exactly with their point of fusion, and many occurrences, often of considerable disadvantage, depend upon it; among the most disadvantageous is, however, that of the so-called burning (*Anbrandes*) which shows itself by rough or file-like surfaces, which take away from the castings all fineness and exactness, and make them look imperfect and almost useless. A closer examination shows that these rough surfaces have been produced by the accumulation of small projections, which partly cover the casting, and with a certain thickness. This appearance is entirely independent of the molder's work, and if the latter has been executed as carefully as possible, and the best casting might have been expected, the surfaces are, nevertheless, covered with projections and grains. The reason for this can, therefore, only be in the quality of the iron. It has been endeavored to ascertain the reason for this chemically, and it is said to have been discovered that the projections forming the rough surfaces were special compounds of iron and other bodies. This, as will be seen hereafter, is correct; but it alone does not explain the mechanical processes that take place in connection with it. Our own opinion on this matter is as follows:

The iron in a fluid state will be no homogeneous body, but a composition of various compounds between iron and phosphorus, iron and sulphur, iron and manganese, iron and carbon, iron and silicium, &c. Each compound has, however, a certain point of fusion, the one lower than the other. Now if mixtures which differ much with respect to their point of fusion form the iron, one portion of the latter will set while the other portion remains in a fluid state, this latter part being forced by the contraction of the former portion through the pores, which are still open during the red-hot state of this portion of the iron, and in this manner the so-called burning or "*Anbrand*" is produced.

After having recognized this cause, it became possible to produce another sort of iron by other charges. The writer is able to show examples of iron upon which are to be seen small balls of the size of peas, in consequence of the great difference between the points of fusion of different parts of the metal. Many other similar occurrences might be explained in the same manner.*

* Professor Gruner, in his article on steel, Annales des Mines, xii, vi serie, 4 liv. 1867, says, "From these results (various analyses of pig-iron) it will be seen that in the varieties of gray pig-iron rich in manganese the silicium is mostly combined with the manganese." Further: "The analyses show that the varieties of gray pig-iron must often contain more than 10 per cent. of foreign bodies, and that their number must be very considerable, &c.; even the white sorts of iron produced from spiegeleisen, which are acknowledged as being very pure, have, in reality, a very complicated composition."

190. A consideration of the facts above stated showing that it is desirable to possess some simple mode of determining the relative points of fusion of different classes of iron, Mr. Schott, the director of the celebrated Ilsenberg Foundery, some years ago devised the following method, which, although of course only capable of affording approximate results. he has found answer well in practice.

An iron vessel, weighing about 25 kilograms, is filled to a certain height with water, so that it contains exactly 48 kilograms. When fluid iron is poured in, the temperature of the water will increase in proportion to the temperature and the volume of the iron; and this increase of temperature is then applied for determining the relative points of fusion of the various sorts of iron in the following manner:

After having measured the temperature of the water, a portion of fluid iron, as taken from the blast-furnace or the cupola, is poured into it as quickly as possible. The water is then stirred, when the temperature is again observed. The water is now carefully tapped off, and the iron is taken out, dried, and weighed. The weight is thus obtained which at a certain temperature produced the observed increase of the temperature of the 48 kilograms of water. Various degrees of heat will produce various differences of temperature, but as it is not always possible to use equally large quantities of iron, while the results are in proportion to these quantities, the following formula has been found to give the relative weight for a certain degree of heat of the iron:

Let the quantities of water used in two experiments, carried out in the way above described, be represented by W and w respectively, and let also I and i be the corresponding quantities of iron used; T and t the differences of temperature produced in the water, and H and h the quantities of heat imparted to the latter per unit of weight of the iron. Then evidently

$$\mathrm{H} :: h = \frac{\mathrm{W\,T}}{\mathrm{I}} :: \frac{w\,t}{i}.$$

But the quantity of water is constant, or $\mathrm{W} = w$, therefore

$$\mathrm{H} : h = \frac{\mathrm{T}}{\mathrm{I}} : \frac{t}{i}, \text{ or } \mathrm{H} : h = \mathrm{T}\,i : t\,\mathrm{I},$$

whence it follows that, if we give the result, H, obtained, in any one instance a certain standard value, the corresponding value of h, derived from another experiment, will be given by the simple formula:

$$h = \frac{\mathrm{H} \times t \times \mathrm{I}}{\mathrm{T} \times i}.$$

It is evident that H and h, instead of being expressed in pound-degrees of heat given out per unit of weight of iron, may, for practical purposes, be more conveniently expressed by the degrees of temperature representing the respective melting points, and this is really what is done at Ilsenberg, the temperature of 1,200 degrees Reaumur (2,732 deg. Fahr.) being taken as the standard value, while differences of temperature of 370 degrees Reaumur (864½ deg. Fahr.) have been found. It is

to be noted that this mode of estimating relative melting points takes no account of the latent heat set free during the solidifying of the iron, but regards all the heat imparted to the water as if it were merely due to the sensible heat abstracted from the iron during its cooling down from the melting point. No doubt this fact introduces an error, while other errors may be induced by the want of care in pouring the iron into the water just before setting; but these errors do not affect the value of the system as a rough-and-ready practical method of ascertaining the relative fusion points of different samples, and, as we have said, it has been found effective and useful at the Ilsenberg foundery.

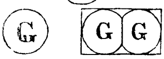
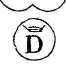
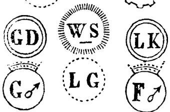
APPENDIX.

TABLE SHOWING SEVERAL MARKS OF SWEDISH IRONS.*

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	PROVINCE OF NORRBOTTEN.			
S: B:	Gellivore	Råneå	300	Gellivare.
	PROVINCE OF WESTERBOTTEN.			
HR RH	Hörnefors	Umnea	1, 100	From middle of Sweden.
ICP	Olofsfors	Nordmaling	300	Id.
RI AB	Robertsfors	Änäsen	600	Id.
FSL	Säfvare	Umnea	180	
	PROVINCE OF WESTER NORLAND.			
CNF	Björkå	Nyland	150	From Lenaberg, Norberg, and Utö.
	Forsse	Nyland	1, 400	Id.
	Graninge			
S	Sollefteå			
× SB ×	Galtström	Sundsvall	380	From Utö, Bispberg, etc.
G	Gideå	Örnsköldsvik	350	
ER	Gåhlsjö	Nyland	170	From Lenaberg, Norberg, and Utö.
Ö L-ö	Lögdö	Sundswall	175	From Stochenström, Utö, etc.
MF PD	Matfors	Id	200	
	Norafors	Id	175	From Staf.
CH Bå NG	Sörfors, etc	Id	600	From Roslag.
TH	Torpshammar	Id	230	
WL	Westtanå	Hernösand	340	
KLP	Åviken	Sundswall	130	

* Reprinted from the Report on Iron and Steel at Paris, 1867, by A. S. Hewitt.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	PROVINCE OF GEFLEBORG.			
SM	Andersfors	Hudiksvall	150	
AB B P	Axmar	Gefle	1,100	From Utö, Enkärn, etc.
B E	Forsbacka, (for steel)	Gefle	850	From Tuna, Hartberg, etc.
FG	Gamelstilla	Thorsåker	430	From Bispberg, Norberg, and Thorsåker.
O	Grönzinka	Gysinge	440	From Norberg, etc.
B	Gysinge	Id	940	From Dannemora.
FG E: P: HP VP CP RP HP	Hammarby Kungsfors and Uhrfors Hofors Montros Robertsholm	Thorsåker	2,300	From Bispberg, Norberg, and Thorsåker.
DE & C:o	Högbo and Sandviken	Gefle	....	From Bispberg and Thorsåker.
R W-n CR	(For gun-barrels.) Kihlafors (For steel.)	Söderhamn	1,100	From Hammarim and Norberg.
	Ljusne	Id	430	From Norberg, Utö, Striburg, Dannemora, etc.
ST LB	Långvind	Id	680	From Wigelsbo, Utö, and Herräng.
	Mackmyra	Gefle	370	
G×B	Orkelbo	Id	1,500	From Vintjern.
T BM	Oslättfors	Id	600	From Bispberg, etc.
	Ström	Hudikswall	720	From Östanberg, etc.
S v.	Svabensverk	Falun	550	From Vintjern.
	Tolffors	Gefle	260	From Bispberg.
W	Woxna	Bollnäs	630	From Gymås and Sörskog.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	PROVINCE OF UPSALA.			
	Elfkarleö	Tierp	430	From Dannemora.
	Gimo	Upsala	280	Id.
	Leufsta	Tierp	700	Id.
	Strömberg	Id	450	Id.
	Söderfors	Id	850	Id.
	Wattholma	Upsala	255	Id.
	Österby	Id	1, 500	Id.
	PROVINCE OF STOCKHOLM.			
	Forsmark	Tierp	520	From Dannemora.
	Skebo	Norrtelje	830	Id.
	Harg	Östhammar	430	Id.
	Rånäs	Stockholm	230	Id.
	PROVINCE OF STORA KOPPARBERG.			
	Avesta	Avesta	180	
	Dalfors	Gagnef	470	From Hamsart, Sörskog, and Gymås.
	Dådras	Falun	350	From Vinjurn and Skinnaräng.
	Fredriksberg	Gagnef	1, 100	From Byberg and Grängesberg.
	Fredshammar	Mora	770	From Åhl, etc.
	Farudal	Gagnef	650	Brom Åhl and Harmsarf.
	Garpenberg	Avezta	860	From Bispberg and Lång vik, etc.
	Gravendal	Gagnef	1, 100	From Grängesberg.
	Grängshammer	Säter	1, 100	From Gräsberg, etc.
	Hagge	Suedjebacken	1, 400	Grängesberg.
	Horndal	Avesta	510	From Bispberg, etc.
	Kloster	Hedemora	940	From Rällingsberg.

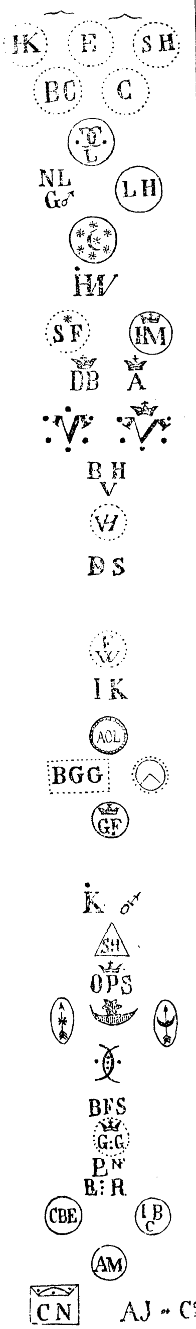
Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	Kloten and Granhult	Köping or Ramsberg	980	From Grängesberg, Lomberg, and Ramsberg.
	Korsä and Svartnäs	Falun	1, 600	From Vintjern and Skinnaräng.
	Larsbo	Smedjebacken	600	From Ostanberg, Norberg.
	Limå and Noraå	Gagnef / Falun	920	From Tuna Hästberg.
	Lindesnaes	Gagnef	1, 500	From Gräsberg.
	Snöå	Gagnef	900	From Sommarberg, etc.
	Ludvika	Smedjebocken	1, 600	From Ivike, Främmundberg, Finnås and Håksberg.
	Långö	Mora	270	
	Malingsbo	Wik	510	From Grängesberg, etc.
	Norn	Hedemora	280	From Bipsberg.
	Norså and Olofsfors	Smedjebocken	230	
	Nyhammar	Id	1, 600	From Grängesberg and Ivike.
	Siljansfors	Mora	280	From Sörskog, etc.
	Stjernsund	Hedemora	280	From Bispberg and Norberg.
	Thurbo and Wikmanshyttan (Cast steel.)	Hedemora	760	From Bispberg and Norberg.
	PROVINCE OF WESTERÅS.			
	Baggå	Köping	470	From Gräsberg and Nyberg.
	Berntshammar	Id	410	
	Bjurfors	Norberg	270	From Norberg.
	Engelsberg	Id	320	Id.
	Fagersta	Id	1, 200	Id.
	Ferna	Köping	1, 700	From Gräsberg, Nyberg, and Grängesberg.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
GBR HI KI	Gislarbo	Köping	900	From Riddarhytta.
CN	Hallstahammar	Strömsholm	450	
HF PB	Högfors and Persbo	Norberg	250	From Norberg.
N	Jäder	Arboga	280	
 S P, GÖ GH	Karmansbo, etc	Köping	1,300	From Norberg and Grängesberg.
WH BC, LLC LL	Kolsva	Köping	1,200	From Stripa, etc.
RB	Ramgäs	Westerås	940	From Östanberg, etc.
IA	Seglingsberg	Id	430	From Norberg.
VR	Skattmansö	Enköping	260	
SG	Skinnskatteberg	Köping	680	From Billsjö and Norberg.
S h	Surahammar	Westerås	1,400	From Norberg.
BK SVANÅ 	Svanå	Id	760	Id.
T	Trångfors	Strömsholm	190	
IW	Uttersberg	Köping	340	From Gräsberg, Tyskgrafva, etc.
HI L	Westanfors	Norberg	190	From Norberg.
	Wirsbo	Westerås	430	

PROVINCE OF ÖREBRO.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
GK GK	Aspa	Askersund	490	From Nora.
BF, BFW BFC PPS	Bofors	Cariskoga	1,000	From Persberg and Nora.
EH	Bohr	Lindesberg	160	From Lomberg, etc.
	Bredsjö	Nora	170	From Ösjöberg, Gröndal, etc.
GR	Brefven	Kilsmo W. S. B.	350	From Nora and Lanna.
FCK	Bångsmedjan	Nya Kopparberg	140	From Lomberg, etc.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
K	Degerfors Ö	Åtorp	150	From Dalkarlsberg and Striberg.
WC H	Degerfors N	Degerfors N.W. S. B.	850	From Persberg, Dalkarlsberg, Striberg & Viker.
K	Elfstorp	Nora	720	From Högborn.
PF	Frötuna	Arboga	390	
Common marks: GD F, G, WE, D, R	Gammelbo	Company of Gammelbo: Ramsberg	270	Prom Ramsberg and Pershytta.
	Finnåker	Arboga	1,050	
	Grönbo	Id	220	
	Ramshytta	Nora	120	
GB	Garphyttan	Örebro	260	From Pershytta and Mografva, etc.
HH AH	Gryn	Pålsboda W. S. B.	1,020	From Nora.
V	Haddebo Ö	Id	210	Id.
PW B^{S}	Haddebo N	Id	290	Id.
	Hammarby	Nora	1,000	From Hagby, Lerberg, etc.
MF W^{r}	Hasselfors	Hasselfors N. W. S. B.	600	From Dalkarlsberg, Striberg, and Viker.
C H HS LS1 C	Hellefors	Grythyttehed.	2,810	From Lomberg and Svarvik, etc.
IE	Högfors	Nya Kopparberg	120	Id.
S×L L^{S}	Lassåna	Laxå W. S. B.	430	From Nora.
HSH	Laxå	Id	850	From Dalkarlsberg, Striberg, and Viker.
	Petersfors	Nora	150	From Jernboås.
	Ramsberg	Ramsberg	150	From Stråssa and Blanka.
PV	Ramshytta	Id	140	Id.
K·	Rockesholm	Nora	260	From Skärhytta and Högborn.
DSR	Rockhammar	Arboga	1,050	From Stripa, Mossgnefva, etc.
	Sikfors	Grythyttehed.	150	From Finnberg, etc.
CWS Mn	Skogaholm	Pålsboda W. S. B.	510	From Nora.
ØB	Skyllberg	Hallsberg W.S. B.	800	From Nora.



Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	Stjernfors	Nya Kopparberg.	470	From Lomberg and Svartvik, etc.
	Svartå	Svartå N.W. S. B.	700	From Dalkarlsberg, Striberg, Viker, & Persberg.
	Walåsen	Cariskoga	360	Id.
	Willingsberg	Örebro	500	Id.
	Wrethammar	Ramsberg	130	From Stråssa and Blanka.
	Åbyhammar	Arboga	170	
	PROVINCE OF SKARABORG.			
	Forsvik	Karisborg	300	From Nora.
	Fredriksfors	Wassbacken	270	Id.
	Lagerfors	Moholm W. S. B.	300	Id.
	Ribbingsfors	Mariestad	350	Id.
	Skagersholm	Finnerödja W. S. B.	430	Id.
	PROVINCE OF CARLSTAD.			
	Ackhärn	Christinehamn	550	From Filipstad.
	Bada Ö	Sunn	150	Id.
	Björneborg and Jonsbol	Christinehamn	1, 000	From Persberg, Dalkarlsberg, Streberg, & Viker.
	Borgvik and Brunsberg	Carlstad	2, 000	From Persberg.
	Brattfors, etc	Id	850	Id.
	Charlottenberg	Arvika	400	From Persberg and Nora.
	Dömle	Carlstad	470	From Filipstad.
	Edsvalla	Id	940	Id.
	Elfsbacka	Carlstad	1, 280	From Nordmark and Finshytta.
	Fredros	Arvika	425	
	Glasfors	Ökne	340	
	Gustafström	Grythyttehed	550	From Persberg, Björn höjde, Fagerberg, and Långvan.
	Helybodafors	Arvika	160	

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
K:	Håkanbol	Åtorp	230	From Dalkarlsberg.
CH KB D S	Högfors	Sunne	630	
BE UvA	Kolsäter	Ökne	210	
J.S. OPS C	Krontorp	Christienhamn	370	
RF, GF, IE, UF.	Llnnartsfors	Ökne	800	
LP GE	Lesjöfors	Filipstad	1,200	From Långban and Persberg.
NM JCG CGG	Lethafors	Råda	220	
K: PC	Lidefors Ö	Åtorp	150	From Dalkarisberg and Striberg.
K: OL	Lidefors N	Id	160	Id.
S:H LNS	Lindfors	Carlstad	850	From Persberg.
OAS MM	Löfstaholm	Sunne	280	
MFS	Mitandersfors	Id	200	
OK MB	Mölnbacka	Carlstad	850	From Persberg.
GL Nm	Niclasdam	Christinehamn.	280	
INN	Noreborg	Arvika	140	
IK N	Norum	Carlstad	150	
Ö	Qvarntorp	Id	170	
IGG	Ransäter Ö	Id	160	
F EF	Ransäter	Id	180	
HK CGG	Rans er N	Id	160	
RD RH GS	Rottnedal	Sunne	640	
6 LD 6	Rämen or Lijendal	Filipstad	680	From Långban, Persberg, and Filipstad.
IL Ł W CIG SB	Storfors	Christinehamn.	1,530	From Persberg and Nykroppa.
HK	Stömnedl	Carlstad	260	
CÜ ÜG	Svaneholm	Åmål	460	From Filipstad.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
WR RF	Sälboda	Arvika	1,230	From Persberg.
	Thorsby	Sunne	630	
LB ÆB C.F OF W.F	Uddeholm	Råda	4,300	From Taberg, Nordmark, Persburg, and Långban.
OPS	Wassgårda	Christinehamn	230	
	Wägsjöfors	Sunne	170	
	PROVINCE OF ELFSBORG.			
BF	Bäckefors	Åmål	1,520	From Persburg.
CD LF	Christinedal	Id	460	
IGE AE GM	Forsbacka	Id	390	
KB	Kollerö	Uddevalla	700	
V	Upperad	Wenersborg	320	
	PROVINCE OF NYKÖPING.			
F	Forssa	Katrineholm W. S. B	260	
Z	Forssjö	Id	310	From Skalunda, etc.
K	Krämbol	Id	230	
Ny	Nyby	Thorshälla	340	
	Nyköping	Nyköping	630	
	Skepsta, (steel)	Björnlunda W. S. B	350	
	Smedstorp	Malmköping	170	From Staf.
GS W	Virå	Norrköping	260	
	PROVINCE OF ÖSTERGÖTLAND.			
BR	Borggård	Tjellmo	260	
IB	Borkhult	Söderköping	190	From Utö, etc.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
B b	Boxholm	Boxholm	640	
B	Börggjöl	Norrköping	160	
FG F:G TGE N:G	Finspong	Id	2,200	From Upsala, Striberg, Utö, etc.
C:F:	Folkström	Tjellmo	510	
DG	Godegård	Hallsberg W. S. B.	270	From Nora and Sanna.
CDB	Grytgjöl	Tjellmo	180	
H	Hult	Norrköping	250	
HJ	Håfla	Id	600	From Nora.
NT	Hättorp	Tjellmo	170	
Æ AL	Ljung	Linköping	550	
L	Lemneå	Tjellmo	310	
MW	Motala Werkstad	Motala	2,100	
S-C	Skönnarbo	Tjellmö	380	
.m.	Sonstorp	Norrköping	550	
	PROVINCE OF CALMAR.			
Am A	Ankarsrum	Westervik	830	From Stenbo, Nartorp, Sjösa, Herräng, and Norberg.
E	Ed	Söderköping	280	From Stenbo, Herräng, Utö, and Nartorp.
IB	Falsterbo	Westervik	260	From Skramstad, Öbalen and Utö.
TF	Fogelfors	Staby	310	From Striberg and Sahlsta.
T	Tofverum	Wimmesby	170	
	Öfverrum	Åtvidaberg	350	From Sjösa, Utö, Stensnäs, Olofsrum, etc.

Mark.	Name of works.	Post-office.	Annual production in tons.	Principal ores.
	PROVINCE OF JÖNKÖPING.			
PI	Eckersholm..........	Jönköping........	140	From Taberg.
:Æ:	Göthafors...........	Id	180	Id.
Æ:	Hörle................	Wernamo.........	390	Id.
:L.F: :Æ: LFN	Lindefors...........	Wrigstad.........	290	Id.
NF: NFN	Nissafors	Jönköping........	370	From Taberg and Nora.
	PROVINCE OF KRONOBERG.			
AB	Böksholm............	Wexiö.............	160	
KS	Klafreström	Id	150	
D.S. L.B.	Lessebo..............	Id	240	
OF	Orrefors	Id	240	
S.F.	Stenfors	Id	210	
S S S	Säfsjöström.........	Id	190	

For information as to the prices and qualities of the irons, one can write directly to the forges themselves. For example: "Brukskontoren à Säfsjöström, Wexiö, Sweden;" or "Brukskontoren à Nissafors, Jönköping, Sweden," &c.

But as all the marks are not indicated here, and since all the forges have agents, it will be better to ask the name of their agent, who will be able to give all the necessary information.

INDEX.

F.

METALLURGY OF LEAD, SILVER, ETC.

H. PAINTER.

VIENNA INTERNATIONAL EXHIBITION, 1873.

REPORT

ON THE

METALLURGY

OF

LEAD, SILVER, COPPER, AND ZINC

BY

HOWARD PAINTER,

HONORARY COMMISSIONER OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

METALLURGY.

ERRATA.

The author, who has been professionally engaged in the mining-districts of the West, did not receive proofs of this report, and desires to make the following corrections and alterations:

Page XIII, line 30, read "Tajova."
Page XIII, line 38, read "Tajova."
Page XIII, line 46, read "Reichverbleiung."
Page XV, line 9, read "Nagy Banya."
Page 2, line 10, read "the policy."
Page 3, line 2, omit "&."
Page 4, line 6, read "tetrahedrite."
Page 4, line 13, for "1.45" read "145."
Page 4, line 37, for "3.5" read ".35."
Page 5, line 9, for "silverized" read "desilverized."
Page 5, line 23, add, at end of line, "silver."
Page 5, line 25, read "Flachs."
Page 6, line 8, insert a comma after "zinc."
Page 7, line 24, read "that country."
Page 12, line 7 from bottom, omit all after "cent."
Page 13, line 23, omit comma after "iron."
Page 14, line 1, omit "a."
Page 14, line 10, read "Arabians."
Page 14, line 27, for "Russia" read "Prussia."
Page 15, line 13, for 0.06" read "0.6;" for "0.11" read "1.1."
Page 22, lines 24–26, read "10,740,000;" "14,955,000;" "25,695,000."
Page 25, line 12, insert "cwt." between "127½" and "copper."
Page 27, line 29, read "for" after "smelting."
Page 30, line 8, read "OKER SAIGER."
Page 32, line 9 from bottom, semicolon after "silver."
Page 33, line 1, omit dash, and insert comma after "pipe."
Page 34, line 18, read "Erbstolln."
Page 34, lines 24–27, read "47,505.64;" "13,070.44;" "34,433.20."
Page 35, line 44, for "sulphuric" read "sulphurous."
Page 36, line 10, omit "two of."
Page 37, line 3 from bottom, read "smelting."
Page 38, line 6, omit ", and" and insert "; as it."
Page 38, line 46, for "0.782" read "0.0782."
Page 39, line 34, omit comma after "ore."
Page 39, line 35, omit "and."
Page 43, lines 19–20, transpose the words "upper" and "lower."
Page 44, line 10, for "9,400 cwt." read "6,000 kilograms."
Page 44, line 13, for "9,600" read "10,000."
Page 49, line 28, omit "1–5" and insert "1, 5."
Page 51, line 22, for "20,000 and 12,500" read "4,000 and 125."
Page 58, line 3, for "millimeters" read "meters."
Page 58, line 47, for "0.003" read "0.03."
Page 65, line 7 from the bottom, for "1,000" read "7,000."
Page 76, line 21, for "3,500 to 4,000" read "35,000 to 40,000."
Page 76, line 31, for "strong" read "light."
Page 81, line 26, read "100 cwt."
Page 83, line 43, omit "as."
Page 84, line 9, for "oxide" read "sulphide."
Page 84, line 18, omit comma after "siliceous."
Page 89, line 32, for "upper" read "under."
Page 94, line 22, read "sulphate of copper."
Page 94, line 23, read "sulphate of copper."
Page 94, line 43, for "hurried" read "humid."
Page 100, line 12, for "slimo" read "slime."
Page 101, line 40, for "meters" read "per cent."
Page 106, line 32, for "to" read "from."
Page 108, line 4, insert "; it" between "copper" and "is."
Page 119, line 28, for "smelting" read "melting."
Page 122, line 12, for "millimeter" read "meter."
Page 124, line 44, for "break" read "treat."
Page 125, line 2, after "zinc" insert a semicolon.
Page 127, line 26, omit "natron" and insert "soda."

Page 127, line 28, after "acid" insert a semicolon.
Page 128, line 1, omit comma after "Herzog."
Page 134, line 11, for "1830" read "1843."
Page 134, line 15, for "view" read "review."
Page 135, line 11, omit "iron" and insert "copper."
Page 135, line 28, for "blast" read "roasting."
Page 140, line 24, for "abstract" read "abstrich."
Page 141, line 2, after "combine" insert "a."
Page 141, line 19, for "cast" read "wrought."
Page 142, line 26, for "estimated" read "eliminated."
Page 143, line 23, for "running," read "mining."
Page 144, line 11, for "pisquisilicate" read "bisilicate."
Page 145, line 4, insert a comma after "by zinc."
Page 145, line 17, add, after "zinc," "chloride of potassium, and chloride of magnesium."
Page 147, line 34, for "Fig. I," read "Fig. III."
Page 148, line 41, for "purer" read "impurer."
Page 150, line 19, for "a" read "attached."
Page 150, line 35, read "Binsfeldhammer."
Page 153, line 14, for "45" read "4.5."
Page 153, line 29, for "20" read "2."
Page 154, line 24, omit "to 0" after "2."
Page 154, line 29, for "70" read "7."
Page 156, line 14, for "quicksilver" read "water."
Page 156, line 22, for "desilverization" read "desilverized."
Page 157, line 9, read "Zsarnowitz" and "Tajova."
Page 157, line 10, for "Barya" read "Banya."
Page 158, line 13 from bottom, insert brackets before and after "English."
Page 159, line 24, for "washing" read "roasting."
Page 163, line 6 from bottom, omit "these" and insert "the following."
Page 163, line 35, for "1,822,688" read "1,822.688."
Page 164, line 12, for "crystallizing" read "cupellation."
Page 167, line 25, insert "a" after "first."
Page 167, lines 25–26, omit "0.5 to 1 per cent. iron."
Page 169, line 39, for "sulphate" read "sulphide."
Page 172, line 41, make the words "for about an hour" follow the word "decreased."
Page 173, line 21, read "Kuschel zinc."
Page 175, line 28, for "ton" read "cwt."
Page 177, line 6, for "smelting" read "meltings."
Page 177, line 7, for "crucible furnaces" read "crucibles."
Page 179, line 2, read "Zsarnowitz."
Page 180, lines 38–39, transfer comma to follow the word "furnace" instead of after "combined."
Page 183, line 28, for "*wasting-dump*" read "*roasting-dump*."
Page 184, line 5, for "gadens" read "Wardein."
Page 213, line 32, Siebrugburger read "Siebenbürger."
Page 215, line 34, for "50" read "0.5."
Page 216, line 1, for "30" read "0.3."
Page 216, line 4, for "Atridaberg" read "Atvidaburg."
Page 221, line 33, insert "west of north" after "80°."
Page 223, line 1, for "1870" read "1872;" for "7,568,942" read "62,000,000."
Insert foot-note after table as follows:

"The value of the metals produced in the United States is estimated; the production of other countries is from official sources. The production of the six mining districts of Germany and of the eight of Austro-Hungary is first given separately, and then the total of all under the headings of Germany and Austro-Hungary. The production of these districts should, therefore, be subtracted from the total production, which would then read:

"Lead, 264,882,398 kilograms; silver, 266,262 kilograms; copper, 45,037,102 kilograms; zinc, 131,204,392 kilograms.

"With the exception of the United States, of which country the production is given *in dollars*, the figures given show approximately the total production of lead, silver, copper, and zinc for the world."

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Production of antimonial lead.

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Andreasberg.

Lautenthal.

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Cupellation.

Zalathna.

B. *Regulations for the purchase of Saxon ores at the Royal Saxon Fiscal Smelting-Works*

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METALLURGY.

LEAD, SILVER, COPPER, AND ZINC.

INTRODUCTION.

Mining and metallurgy were justly placed in the first group in the general classification of the Vienna Exhibition. Mining and smelting are not only a principal source of raw material, but their products have taken in the past an important part in the history of the human race. They are, and will always be, an indispensable necessity of the never-ceasing demands of the manufacturing interests, and the further progress of every branch of industry, and therefore necessary to the advancement of civilization and the welfare of mankind.

The art of metallurgy was not as well illustrated by most of the countries represented as that of mining. The larger exhibit of rocks, vein-pieces, minerals, ores, &c., was more intended to show to the world the mineral resources and their connection with the geological formation of the several countries than the condition of the methods employed in the extraction of the various metals at the present day.

Iron, lead, and copper ores, and metallurgical products, constituted the principal metallic display of all countries rich in minerals.

Norway, whose characteristic metal is copper made an exception to the above. Silver and zinc ores were but poorly represented.

The British display, in Group I, was confined to iron-ores and their products, and machinery. There were several collections of gold and silver ore from the English colonies.

The method of exhibition, considered from a professional point of view, was a very unfortunate one. The articles belonging to Group I were scattered throughout the entire Exhibition, thus making it exceedingly difficult for those seeking information on this particular subject to gain a thorough oversight of the products exhibited.

The great importance of this branch of industry demanded that it should have had a separate and distinct building, (as the machinery building,) where the products from all countries could be exhibited, and a comprehensive and connected view of the whole offered to the visitor.

The quality of the exhibited products was not to be ascertained by a superficia examination, such as even the International Jury was compelled to make.

More reliable, though not entirely so, was the information offered to the public by several metallurgical establishments. This was generally in the form of a survey of the process practiced and the extent of their

operations. It should be here remarked, and the remark is applicable to all cases where interested persons describe the methods of extraction and the economical practical results obtained, whether orally or in writing, that only the most favorable cases and results are given; or, if an unfavorable result should be mentioned, it would be explained away as though it were an unavoidable consequence of something connected with the manipulation. This is the general rule. It is not seldom the case that falsehoods are intentionally and foolishly told concerning the process. The several inducements for this are apparent, but policy is short-sighted and weak. For this reason, such articles emanating from interested persons should be received with due caution and consideration.

There have been but few important metallurgical processes or apparatus discovered since 1863. These consist in the Gerstenhöfer, Hassenclever and Helbig, Stetefeldt, and Kuschel and Hinterhuber's roasting furnaces; the Pilz round smelting-furnace, with widened top, iron water-cooling boxes, and tuyeres, and Cordurié's method of eliminating zinc, and other elements, from lead.

The constant increase in wages, fuel, and material, without a corresponding increase in the price of the products, have made rapid and great improvements necessary for successful metallurgical operations. The immense strides that have been made in this branch of industry have been principally made toward increasing the production, viz, by increasing the size of the furnace and the pressure of blast; but of greatest importance is the production of poorer waste-products, as slag, and by extracting small quantities of silver and gold, (improved zinc-desilverization,) and the construction of extensive condensation-chambers.

In preparing this report, the products, exhibited at the Vienna Exhibition have first been enumerated and described, with the methods and the latest improvements employed in their production, together with statistics illustrating the scale on which the above operations are conducted.

As the data obtained at the Exhibition was in most cases deficient and seldom of a uniform nature, I have had recourse to private notes, made when visiting the several metallurgical works in the years 1869 to 1874, and to the communications of several gentlemen, which are duly credited in the proper places. I avail myself of this opportunity to acknowledge my thanks and indebtedness for courtesies and valuable information to my associates on the jury, the Austrian minister of agriculture, Vilmos Ocsovszky, mayor of Schemnitz; W. Wiesner, director of mines in Schemnitz; Vilibald Kachelmann, director, and Joseph Wagner, assayer, of the government smelting-works at the same place; Franz Markus, director of the Neusohl smelting-works; I. Langer, superintendent of the Pribram smelting-works; Mr. Kast, director of the Clausthal smelting-works; E. J. Strauch, director, and W. Schmidt, assessor, at the Lautenthal smelting-works.

CHAPTER I.

EXHIBITS OF THE UNITED STATES.

EXHIBITS OF H. T. BLOW, SANTEE & WAGNER, GRAND PIER MINING AND MANUFACTURING COMPANY, MINERAL CITY MINING AND SMELTING COMPANY, E. B. WARD, JOSEPH WHARTON, P. P. PECK, GUIDO KÜSTEL; METHOD OF ZINC-DESILVERIZATION PRACTICED AT THE GERMANIA SMELTING AND REFINING WORKS; EXHIBITS OF THE SUTRO TUNNEL COMPANY.

1. The display of metallurgical products from the United States was very small; only two lead and smelting works being represented. The mineralogical specimens exhibited were more numerous, and of great interest to those seeking information relating to our extensive mineral resources.

The following are the ores and products exhibited:

2. By Mr. H. T. Blow, of Saint Louis, Mo.: Calamine and galena, from Granby; both the minerals were in remarkably large crystals. The cubes of galena were about 12 centimeters in diameter.

3. By Messrs. Santee & Wagner, Rolla, Mo.: Galena, blende, and copper-pyrites.

4. By the "Grand Pier Mining and Manufacturing Company," of Shawneetown, Ill.: Galena, blende, copper-pyrites, fluor-spar, and baryte.

5. By the "Mineral City Mining and Smelting Company," of Mineral City, Ill.: Fluor-spar, which is used extensively in the manufacture of glass; galena with about 0.06 per cent.=17 oz. 9 dwt. 19 gr. silver, and lead-ore with 68 to 79 per cent. lead. These mines have not yet been developed, but it is proposed to commence operations on a large scale as soon as the necessary capital can be obtained. The ore-deposits are said to be extensive.

6. By Mr. E. B. Ward, Detroit, Mich.: Copper-pyrites and native silver.

7. By Mr. Joseph Wharton, Philadelphia, Pa.: Magnetic pyrites from the Gap mine, in Lancaster County, Pennsylvania, containing 1 per cent. copper, 1.75 per cent. nickel, and 0.1 per cent. cobalt; millerite; metallic nickel, cobalt, and chemically-pure zinc; alloys of nickel-cobalt, nickel-copper, cobalt-copper, and various salts of nickel, cobalt, copper, and iron. The smelting-works are in Lancaster County, but the nickel and cobalt refining-works are in Camden, N. J. The annual production is 95,000 kilograms nickel, 4,500 kilograms cobalt, and 200 to 500 kilograms copper.

8. By Mr. P. P. Peck, of Denver, Colo.: A collection of gold and silver minerals.

9. By Prof. Guido Küstel, of San Francisco, Cal.: A small but well-

selected collection of gold, silver, and lead minerals and ores from Utah and California. All the specimens displayed were designed to give strangers a comprehensive idea of the minerals occurring in the mining localities in the two sections of the country where they occurred. Of especial interest to the mineralogists, were a series of minerals illustrating the transition of tetrabedrite into stetefeldite. These received much attention from professional men, their value being increased by the accompanying analysis of each specimen.

Several beautiful specimens of wolframite also deserve mention. They were unusually large (1.5 to 2.5 centimeters in diameter) crystals of modified tetragonal tables. The same gentleman also exhibited silver-lead and silver from the "Germania Smelting and Refining Works." The sample of silver-lead exhibited assayed 0.5 per cent.=1.45 oz. 16 dwt. silver, and the silver from the cupellation furnace was $\frac{991}{1000}$ fine.

10. In the year 1872 this company erected smelting-works with apparatus for the desilverization of argentiferous lead by means of zinc.

The following description of the zinc-desilverization process practiced at the Germania Works (which is the only available one) was written by Mr. Bentham Fabian, and appeared in the Salt Lake Tribune of January 4, 1873:

As the original description abounds in impossibilities and improbabilities, only the manipulations of the process are here reproduced. The battery consists of five Pattinson kettles, two of which have a capacity of about 25,000 kilograms; the other three are smaller. The kettles are arranged in the shape of the letter V; the broad part being formed by the two large or fusing kettles, and the smallest kettle forming the apex.

The zinc used is of two qualities, viz, commercial or good zinc, which is brought from Illinois, at a cost of 9 cents per pound; and dross zinc (refuse from galvanic batteries, which contains about 30 per cent. of iron) from New York, at a cost of 5 cents per pound. When the silver-lead is tolerably free from impurities, and contains from 0.5 to 0.7 per cent. =145 oz. 16 dwt. to 204 oz. 2 dwt. silver, about 2.25 to 2.75 per cent. zinc or 3 to 3.5 per cent. zinc-dross is consumed in the desilverization. The manipulations are as follows:

The silver-lead is fused in one of the large kettles,* and the first addition of zinc made, which is 3.5 to 1 per cent. of zinc, or 0.75 to 1.5 of zinc-dross. This is well stirred for half an hour, and then allowed to cool, (the fire being withdrawn,) and remain undisturbed for three hours, when the zinc-scum is removed and ladled into the adjoining smaller kettle. The fire is then raised, and a second addition of zinc is made; this is 0.5 to 0.75 per cent. of zinc, or 1.0 to 1.5 per cent. of zinc-dross, which is stirred, and the metallic liquid is allowed to cool.

* The author of this article has evidently omitted to state that the *abzug*, composed of a portion of the copper, iron, &c., contained in the silver-lead, is removed before the zinc is added.

The zinc-scum which is in the second kettle is now melted, stirred, and allowed to cool; the skimmings, or zinc-dust, are transferred to the third or smallest kettle of the series, and the liquated lead is ladled back into No. 1, or the fusing-kettle; a similar operation is repeated in the third kettle, the scum being set aside for treatment in a shaft-furnace, and the liquated metal ladled back into No. 2. The remainder of the zinc having been added to the metal in the first or fusing-kettle, and the first process repeated, the third zinc-scum is set aside for further treatment. The silverized lead is tapped from the fusing-kettle by means of an iron pipe attached to the bottom of the same, and connecting by means of an iron trough with a reverberatory furnace. It is there subjected to a bright-red heat for several hours, whereby the impurities are eliminated by oxidation.

There are two refining-furnaces, one for each fusing-kettle. The hearth is 15 feet 6 inches long and 9 feet 4 inches wide, with a sufficient depth to contain the contents of the fusing-kettle. The refined lead is tapped from the furnace into a market kettle, and then cast in molds. Each bar of lead weighs about 140 pounds.

The whole operation, from the charging of the silver-lead in the fusing-kettle to the tapping of the refined lead, occupies twenty-four hours; the capacity of the works was, in January, 1873, about 40 tons per day. The refined lead is said to be free from all impurities, and to contain only 0.0003 per cent.=1 dwt. 17.95 gr. (?)

The rich alloy or liquated zinc-scum from the first and second additions of zinc are smelted in a shaft-furnace according to the Flaclis process. The back wall of the furnace is inclined toward the front, and at a short distance above the tuyeres the front wall recedes more abruptly from the back. The furnace is 2 feet 7 inches from breast to back, and 2 feet 6 inches wide. It has three tuyeres, with a diameter of $1\frac{1}{4}$ inches and a pressure of blast equal to about 24 inches water-column. Coke serves as fuel; it is obtained from Pittsburgh, and costs, delivered at the works, about $28 per ton. The hematite used as a flux is brought from Rawlins, and costs about $15 per ton. It contains about 62 per cent. of iron, sesquioxide, and 15 to 20 per cent. of silicic acid. The lead-slag is to be had in the neighborhood. The charge is, rich alloy, 250 pounds; hematite, 180 pounds; coke, 55 pounds, and a small quantity of lead-slag. It will have been observed that the first and second zinc-scum are treated together according to one process, and the third zinc-scum undergoes another treatment. If this is not an incorrect statement, the reason for so singular a method should have been explained. As zinc has a greater affinity for copper and gold than for silver, (and none for antimony,) the two first metals, when contained in the silver-lead, (and they are contained in the silver-lead treated at the Germania Works,) are concentrated in the first zinc-scum. This is at other works set aside and treated by itself. The different constitution of the alloy requires a separate process. The second and third zinc-scums are of a

uniform composition; the third merely containing a smaller amount of silver than the second. Therefore, I think it highly probable that the first zinc-scum is treated in the liquating ("roasting") furnace, and the second and third are liquated together in the smaller kettles. The charge given above is most likely that used in smelting the enriched scum from the second and third additions of zinc, and which is non-cupriferous. In smelting, the enriched scum from the first addition of zinc unroasted matte, or some other substance rich in sulphur, is probably added to the charge, which would be the means of concentrating the copper in the matte. The matte would also contain small quantities of lead and silver, but these could be extracted with a small loss by roasting the matte and adding it to the ore-charge, or desilverizing it by smelting with lead fluxes which are free from silver. Another error here reproduced is, that the pressure of blast is equal to 24 inches=0.62 meter water-column. The maximum pressure of blast is stated by Kerl to be 0.157 meter water-column. The pressure at the Mechernich Works is 0.131 meter; at Ems, 0.13 meter water-column. It is true that when the pressure is too small the amount of zinc volatilized is decreased, but when the pressure is too great, lead (and silver) is volatilized in large quantities, and the formation of salamanders, containing silver and lead, is increased.

11. By the Sutro Tunnel Company, of Sutro, Nevada: Topographical charts and a model of the celebrated Comstock lode. It was of cast iron, and in two sections, so made as to represent the Sutro Tunnel. Information concerning the latter was circulated by means of pamphlets. As the history of and progress made by this gigantic undertaking has long since attracted the attention of the engineering world, this model was regarded with great interest by a multitude of scientific visitors who saw in it professional enterprise which bears the impression of American energy.

CHAPTER II.

SPANISH EXHIBITS.

FROM GRANADA, ALMERIA, HENLON, SANTANDER, THE MADRID MINING ACADEMY, AND THE ALMADEN MINES; AGE AND PROGRESS OF MINING AND METALLURGY; GROWTH OF PRODUCTION.

12. The metallurgical exhibit of Spain was small, and it was only in exceptional cases that the products displayed were accompanied by the name of the locality whence they were. This imperfect representation of Spain's immense metallic treasures is, probably with justice, to be ascribed to the very unsettled condition of the country.

13. Granada and Almeria were represented by specimens of black and refined copper. Hueloa, by pure refined copper.

14. From Santander there were specimens of argentiferous galena, calamine, blende, copper-ores, copper and silver lead.

15. The Madrid Mining Academy exhibited a mineralogical collection, among which were specimens of lead, silver, and quicksilver ores.

16. A very interesting display of cinnabar, native mercury, slag from quicksilver-ores, and mercury, from the celebrated mines of Almaden, was made by Dávilla, Madrid.

17. A great amount of galena and argentiferous lead (chiefly extracted by English companies) is sent to foreign countries, principally to England.

The extraction of the metals in Spain was commenced in ancient times. The Phœnicians, Carthaginians, and Romans imported large quantities of silver from Spain; and this country for a long time was considered the richest country in the world in silver.

Strabo, who gives us the first accounts of the mining and the extraction of silver from its ores, describes the largest and oldest works in Spain, situated at New Carthage.

The extraction of copper from its ores has also been carried on for a long time in Spain. The production of copper has never been great, but the product possessed an excellent reputation with the Romans.

18. A large increase in the production of lead took place in the latter part of the last century. Karsten was of the opinion that Spain probably possessed greater riches in lead than any other country in the world, and was also of the opinion that if the Spanish mines were worked with the same energy as the British, she would easily excel the extraordinarily large production of England. This latter proved in time to be correct, for the same author computed the production of lead

in Spain in the year 1828, or thereabouts, at 25,600,000 kilograms, and this was merely the quantity produced in a few districts. He remarked, at the same time, that full statistics were wanting, and this production took place without any increase of labor or energy; at the same time in England (1828) 46,150,000 kilograms were produced. In the year 1868, forty years later, during which time England had made gigantic strides, the production amounted to 72,200,600 kilograms. In the year 1868, at which time the art of mining and metallurgy in Spain was still at a low point, the production of lead increased to 72,800,000 kilograms, and the difference becomes much greater when it is considered that not a small proportion of the lead produced in England is extracted from foreign, and even from Spanish ores.

CHAPTER III.

FRENCH EXHIBITS.

Exhibits of M. Laveissière et Fils, Manhes Père et Fils, Henry Merle & Co., from Algiers; Progress and condition of Metal Industry; Cordurié's method of Lead Refining; Payen's Method; Rozan's Improvements; Manipulations of Rozan's method; Objections to Rozan's method.

19. The exhibit of metallurgical products from France was very small. An elaborate display was made by M. Laveissière et Fils, Paris, of copper ingots, kettles, also copper and brass pipes of various sizes. The manufactured articles were tastefully and artistically arranged in the dome of the Exposition, so as to represent a feudal castle. The walls and pillars were formed by copper and brass pipes alternating; on the parapet, pipes were made to represent cannons; inverted copper kettles served as arches for the portals.

20. Manhes Père et Fils, of Lyons, exhibited a large number of wrought-copper kettles and rolled sheet-copper.

21. Henry Merle et Cie., of Alais, exhibited several bricks of fine silver.

22. Algiers was represented by several small exhibits of argentiferous galena, silver, and copper ores.

23. The metal industry in France has of late assumed immense proportions. This is partly to be attributed to the increasing commercial facilities of that country and the inventive spirit of the French. France's metallic mineral—*i. e.*, copper, lead, silver, and zinc—resources are far from being extensive, yet owing to the enterprise of her citizens in this great branch of industry, both at home and abroad, it has advanced, until France at present stands at the head of the copper-producing countries, and fourth in lead and silver. Copper-ores are chiefly imported from Chili, lead-ores and silver-lead from Sardinia and Greece.

24. The lead metallurgist is indebted to the French for valuable improvements, the most important of which is, perhaps, the method of refining lead by means of steam, (Cordurié's method,) which, now that the advantages of zinc-desilverization are in Europe and America so universally acknowledged, has become of especial interest.

25. In connection with this subject, it is to be regretted the "new improvement in refining lead and products therefrom," by Thomas Payen, E. & H. Roux, of Marseilles, France, which appeared in the catalogue, (No. 31,) and which was awarded a prize by the International Jury, (Group I,) was, as the writer ascertained by a careful and thorough inquiry, not placed on exhibition. This "improvement" is to be intro-

duced at the lead smelting-works at Marseilles, and it is intended by the use of soda and a small proportion of saltpeter to remove antimony, but especially arsenic, from the silver-lead in the reverberatory refining-furnace. The process is to precede the crystallization desilverization process.

26. An important improvement in pattinsonizing and refining silver-lead by means of steam has been made by M. Rozan, and introduced in Marseilles. This will be of interest not only to those metallurgists who practice the crystallization process, but also to those who may intend erecting separating-works. The description is from the Ann. de Mines, Sept. sér., tom. iii, livr. 2, 1873, p. 160.

The first results of thus applying steam to desilverization were made public in 1871, but the following are the manipulations attending the working of silver-lead containing 0.123 per cent.=35 oz. 16 dwt. silver, as carried out in 1872, together with the exposition of the practicability of the same. The principle of this process is, that by conducting steam into the molten metal contained in a Pattinson pot, the thick, heavy liquid is thrown into a violent commotion, thus dispensing with manual or mechanical stirring. According to M. Rozan, practice has proven that this violently continued action is very favorable to the separation of silver and lead in poor crystals and enriched liquid lead; only very hard lead requires a previous softening. The action of the steam is principally mechanical, but the lead undergoes a partial refining, which is a consequence of different particles of the hot lead constantly coming in contact with the air. As a chemical reaction is not believed to occur, the purity of the commercial lead is partly to be ascribed to the various partial refinings which the silver-lead undergoes by being repeatedly remelted in a red heat. M. Rozan has, however, observed that the steam takes an active part; that the oxides which are formed at the beginning of the crystallization are yellow and dirty; but as the operation approaches the end, they grow dark and contain considerable copper; a circumstance that by the most lively stirring does not occur. At the end of the crystallization, while the steam is bubbling in the liquid lead, in which the silver, copper, antimony, and arsenic have been concentrated, the poor lead is freed from the copper. The action of antimony is not similar, but it is gradually oxidized by the action of the heat and air in the successive re-smeltings. It has also been observed that soft lead, under equal circumstances, produces a greater quantity of oxide than hard lead, especially antimonal lead, (in Tarnowitz,) which proves that antimony oxidizes first, and then prevents the lead from oxidizing. The action of the steam is undoubtedly decisive and strong. It is said that the commercial lead falling from this process is perfectly soft, and contains from 0.0012 to 0.002 per cent.=11 dwt. 15 gr., to 6 dwt. 22 gr. silver. The enriched cupellation-lead contains, according to the nature and contents of the original silver-lead, from 1.6 to 2.0 per cent.,=465 oz. 18 dwt., to 582 oz. silver, while the steam-process universally produces

lead enriched to the above extent, and thus, as we shall presently see, materially reduces the cost of desilverization; it is only accomplished after a great number of operations with the usually conducted Pattinson process. This process possesses not only the advantage of not requiring a special refining of lead, which is not very hard, but is said to be accompanied by a smaller oxidization of lead, and consequently the loss and expenses of resilverization are diminished. There is also a great saving of time and labor. The lead is crystallized in much shorter time than is the case by pattinsonizing, viz, 13 to 16 tons, while with the latter only 9 to 10 tons are treated in the same time. A serious disadvantage in this method is the concentration of antimony and some copper in the rich lead, which causes such objectionable features, by cupellation and undesirable processes, necessary to a subsequent treatment of the products therefrom.

27. The manipulations are as follows: The battery consists of two Pattinson kettles; one kettle is placed so that its bottom is on a level with the top of the second. The upper, or fusing-kettle, is intended for a charge of 9,000 to 10,000 kilograms silver-lead; the lower, or crystallizing-kettle, will contain 15,000 to 16,000 kilograms. After the silver-lead has been fused and the dross removed, it is tapped into the lower kettle by means of an iron pipe attached to the bottom of the upper. At the same time that the silver-lead is tapped from the upper a small amount of steam is conducted into the lower kettle, in order that the crystals from the former operation may be easily mixed with the silver-lead. A small stream of water is now thrown on the surface of the metallic bath, which hastens the cooling and assists the crystallization. Steam is conducted into the metallic bath, under a pressure of three atmospheres, through an iron pipe, which terminates at the bottom of the kettle. The steam upon entering strikes against an iron plate, and is diffused through the bath. The lead is prevented from entering the steam-pipe by means of a hinge-valve. The kettle is covered with a hood, which is connected with the condensation-chambers. The oxides which form are first removed and the operation then commences. The hood is raised every five or ten minutes, and the lead adhering to it is scraped off. The operation is finished when two-thirds of the lead is crystallized. The mother-liquid is then tapped off by means of iron pipes attached to the bottom of the kettles. The crystals are prevented from escaping with the mother-liquid by means of an iron sieve, which is fastened over the pipe. The lead is run into large cakes of 2,500 kilograms each. These are arranged according to their silver contents around the battery; they are added to succeeding operations. The lead-cakes having a larger percentage of silver than the original silver-lead are set aside until a sufficiently large quantity has accumulated for a new series of operations, whose starting-point is based on the silver contained in these cakes. After the enriched lead has been tapped off, a new quantity of lead, which has in the mean time been melted in the

upper kettle, is added to the crystals in the lower. The operations are repeated until commercial lead, or complementary lead, in the form of crystals, is obtained. When the lower kettle is heated the crystals are fused and tapped off. By "an operation" all the manipulations are understood which occur from the tapping of the lead from the upper kettle to the casting of the enriched lead into cakes. One operation lasts one and a half to two hours. The casting of commercial and complementary lead occupies the time of two operations, as the time consumed in melting the crystals is twice as great as that employed in crystallizing the silver-lead. The number of operations represented by the casting of the commercial and complementary lead is, for silver-lead assaying 0.123 per cent.=35 oz. 16 dwt. 1 gr. silver, 25 to 30 per cent. of the whole number of operations. From sixteen to seventeen operations are made in twenty-four hours. This is dependent upon the temperature used. The number of operations necessary for the treatment of a certain amount of silver-lead varies with the silver contents of the same. One battery, which treats silver-lead with 0.123 per cent. of silver, produces 6,000 to 7,000 kilograms commercial lead in twenty-four hours. After the latter has been cast, the kettle is refilled with silver-lead of the original percentage of silver and the operations are continued until all of the complementary lead has been treated with 0.003 per cent.=17 dwt. 11.5 gr. silver. The crystals are then fused and cast into cakes to be used as complementary lead in a new series of operations. Several series of operations are thus repeated, commencing with the original silver-lead, or lead with a greater percentage of silver, and producing enriched silver-lead and commercial lead.

28. A comparison between this process and the mechanical pattinsonizing, as formerly practiced at the works ăt St. Louis Les Marseille, shows that as pattinsonizing costs 46.54 francs, and this process 25.32 francs, this process effects a saving of 20.72 francs per 1,000 kilograms in silver-lead. The lead-loss is 2.1 per cent. in pattinsonizing, and 3 per cent. in the steam process. The silver-loss in each is 1.5 per cent. of the amount of silver paid for according to the assay. The saving is owing to a less number of workmen being employed, by avoiding a preliminary refining, the decreased amount of products which have to be reduced, and, as the concentration is carried farther, (1.7 per cent. = 495 oz. 2 dwt. silver, instead of as in pattinsonizing, 1.15 per cent. = 331 oz. 16 dwt. 14 gr. silver,) so is the decreased cost of cupellation.

29. The objections to this process are the small capacity, large amount of intermediate products, loss of silver (1.5 per cent. = 436 oz. 16 dwt.) and lead, and its complicated nature. Although the communication and calculation made by the inventor show a decided improvement on the mechanical Pattinson process, the method described will scarcely be introduced in works where the virtues of the improved process of zinc desilverization are known, and the silver-lead is of a quality to permit it to be treated by the latter process.

CHAPTER IV.

ITALIAN EXHIBITS.

CONDITION OF METAL INDUSTRY; EXHIBITS OF "COMPAGNIA DEL BOTTINO," DOMINGIKUS ING SANTELLI, SIMONIS CORNELISSEN & CO.; HISTORY, GROWTH, AND CONDITION OF METAL INDUSTRY ON THE ISLAND OF SARDINIA; EXHIBITS BY THE SOCIETA; MISCELLANEOUS EXHIBITS; SMELTING PROCESS; PRODUCTION; COST OF MINING AND SHIPPING ORES.

30. The metal industry of Italy has been so greatly depressed from a lack of fuel suitable for smelting purposes, that it is necessary to export the richest ores for reduction; the poorer ones, that will scarcely pay the transportation expenses, are worked in the vicinity of the mines with a small profit. The copper-ores of Tuscany and Liguria are of the first class, carrying 12 to 25 per cent. of copper, and are exported to England, while those occurring at St. Marcel in the valley of the Aosta, and at Agordo in Venice, belong to the second class, containing about 2 per cent. of copper.

The production of copper in Italy is 300,000 kilograms. The consumption is estimated at over 1,200,000 kilograms. This large difference is obtained from foreign countries.

31. There were exhibited from the works of Agordo, "Stabulimento Mantanistico Governativo di Agordo, Vall Imperina Belluno," samples of refined copper, which is renowned for its superior quality, and is used in the manufacture of articles requiring very pure copper. In addition to this, there were iron, vitriol, and native silver.

32. The "Compagnia del Bottino" of Stazzema Lucca, Tuscany, exhibited silver-lead, litharge, and refined silver. Lead-matte, and also galena containing 27 per cent. of lead, are roasted in Schaft furnaces. It is charged in alternate layers of wood and charcoal and ore. The roasting period is fifteen to twenty days. The lead-matte is lixiviated in the furnace. The solution containing the copper runs out of the furnace into the precipitation-vessel. The sulphurous-acid fumes are allowed to escape into the atmosphere. They are believed to be a preventive against cholera.

33. Domingikus Ing Santelli, of Vinadio Cuneo, exhibited specimens of artificially produced argentiferous galena.

34. Simonis Cornelissen & Co. exhibited artificially produced iron and copper pyrites.

35. SARDINIA.—The greater proportion of the argentiferous-lead and zinc ores, considered as the production of Italy, are obtained from

Sardinia. The lead and silver mines on this island* are a very ancient. They are said to have first been worked principally for silver by the Phœnicians. They were followed by the Carthaginians and Romans. Among the many mining and metallurgical relics discovered in and near the mines is a pig of lead found near the Porto di S. Nicolo which weighed 34 kilograms and bore Hadrian's name.

After being successively under the reign of the Vandals, Goths, and the Byzantine empire, the island became free, and a national government was formed. This had not been long in existence before it was overthrown by the Aribans, who in turn were driven from the island by the Genoese and Pisians. In the thirteenth century, after the island came under the Pisian rule, the first book on mining-law was written. It was in this period that the large lead-slag dumps near Villa-Massargia, Domus Novas, and Flumini Maggiore were formed. The shafts were about this time sunk through the hard rock by means of fire to depths of 80 to 100 and even 200 meters. In the year 1323 the island fell under the Spanish crown. The mineral industry thereupon sank and became almost inactive. This was partly caused by the negligence of the Spanish government, and partly by the discovery of America with its large treasures of gold and silver. The House of Savoy obtained possession of Sardinia in 1720, but it was in 1850 that the mines were successfully worked with renewed vigor, and since that time the production of lead and silver has been steadily increasing. Since 1865 calamine has been mined to a large extent. The richer lead-ores are shipped to Pertusola, in the Gulf of Spezia, France, Belgium, and England; the silver-lead to Genoa and France, and the calcined calamine to England, Belgium, and Russia.

36. The Società Anonima de Monte-Santo of Cagliaza, in Sardinia, exhibited lead which was designated as soft lead, but could hardly be scratched with the finger-nail.

37. There were several small collections of minerals exhibited of different mining companies; these were composed of a few specimens of argentiferous galena, or calamine, or both.

38. Italian smelting process.—There have lately been several works erected with the intention of reducing oxidized ores, poor ores, and the old slags.

The reduction-works of Masua and Fontanamore are, of the six on this island, the most important. The former was built in 1862, and treats oxidized ores carrying 32 per cent. lead and 10 to 12 per cent. zinc. The latter smelts poor ores from Nebida. These ores are smelted in round shaft-furnaces, whose smelting zone is of cast-iron water-cooling boxes. The charge is 50 per cent. slag and 14 per cent. English coke. The blast is produced by a steam-fan. The campaign lasts from Decem-

* Free use is here made of the report "*Sulle Condizioni dell' industria Mineraria nell' isola di Sardegna,*" submitted to the Italian chambers of deputies in 1871, by M. Quintino Sella.

ber until July. The workmen, who are from Piedmont, cannot, on account of fever, remain on the island during the other five months, or the campaign might be still longer. Two furnaces smelt in twenty-four hours 18,000 kilograms of ore, producing in three tappings 375 kilograms lead, carrying 0.9 per cent. to 1.1 per cent.=262 to 320 oz. 8 dwt. silver. The zinc-oxide fumes from the condensation chambers, containing 33 per cent. lead, are agglomerated in a reverberatory furnace and then smelted in a shaft-furnace, producing lead carrying 0.35 to 0.55 per cent.=102 to 160 oz. 8 dwt. silver. The silver-lead is sent to Genoa and France for desilverization. The old slags, containing 10 to 14 per cent. lead, are smelted together with poor ores at the Dumas Novas, Flumini, and Villacidro works. The resulting silver-lead assays 0.06 to 0.11 per cent. =174 to 320 oz. 8 dwt. silver.

Ore and slag have been smelted since 1858 in shaft-furnaces with coke or charcoal. In Masua, poor ores from Montefroni were added to the lead-slag, and the mass first agglomerated in a reverberatory furnace, and then smelted in shaft-furnaces. The lead-slags have been all smelted, and, on account of contracts having been made with metallurgical companies in Marseilles, England, Belgium, and Prussia, for large quantities of the rich ore, for a long period, the Sardinia smelting-works will have to confine their operations to poor ores; were they not thus bound by their contracts, they might obtain a sufficient supply of coal at reasonable rates, brought to Sardinia as ballast by the vessels which carry a portion of the ores to England and Belgium, as the works at Pertusola, in the gulf of Spezia, have obtained their fuel for several years.

39. Sardinia produced in 1868–'69—

	Kilograms.
Lead-ore exported, 14,706,000 kilograms, valued at 7,515,699 lira*, contains 70 per cent. lead=10,244,200 kilograms; deduct 8 per cent. loss in reduction=62 per cent. lead extracted from ore=	9, 117, 820
Lead-ore and blende reduced in Sardinia, 990,900 kilograms, valued at 120,265 lira, contains 20 per cent. lead=	198, 650
	9, 316, 470
Calamine, 39,113,950, valued at 5,601,812 lira, contains 47 per cent. zinc=	18, 383, 556. 5

40. The statistics of cost of mining and transportation of ore to the vessels will, doubtless, be very interesting to American miners.

In the calculation of the value of ore, the price of lead in Marseilles is taken as the basis. The buyer estimates the cost of smelting at 60 to 70 lira; of desilverization at 60 lira per ton, and a lead loss of 7 to 9 per cent. The silver is paid for at the rate of 21 centisimi per gram.

The price of zinc in London is taken as the basis, and ore containing 45 per cent. zinc is, accordingly, worth on board the vessel from 43 to 69 lira.

* The *lira* is equivalent to 19 cents in the coin of the United States.

One ton of lead-ore:

	Lira.
Mining	55.95
Hoisting out of mine	16.19
Separating and dressing	11.40
Transportation on board ship	22.76
Superintendence, &c	20.00
Various items	6.03
	132.33

The company, Malfidino, engaged in mining calamine near the coast, presents the following calculation of mining expenses, &c.:

	Lira per ton.
Mining	9.33
Calcining	9.05
Transporting from the mine to the coast	4.05
Transporting from coast on board vessel	10.01
General expenses	4.00
	36.44

CHAPTER V.

BELGIAN EXHIBITS.

EXHIBITS FROM BLEYBERG; BLEYBERG SMELTING PROCESS; COMPARISON OF BELGIAN AND ENGLISH REVERBERATORY SMELTING-FURNACE; EXHIBIT OF THE ZINC MINING AND SMELTING COMPANY OF LA VIEILLE; HISTORY OF THE ZINC MINING COMPANY AND DESCRIPTION OF THE WORKS.

41. The Société Anonyme du Bleyberg Ésmontzess exhibited a very interesting collection of minerals, ores, and metallurgical products, which was composed of dressed and undressed lead and zinc ores, silver-lead, a large cake of silver from the cupellation-furnace, refined commercial lead, guaranteed not to contain 0.00488 per cent. of impurities, (copper, antimony, silver, &c.,) homogeneous antimonial lead, commercial zinc, and various other metallurgical products, viz: mengite, red and yellow litharge, cadmium sulphide, fumes from the condensation-chambers, and lead-matte.

42. BELGIAN SMELTING PROCESS.—The Bleyberg lead-ores carry about 80 per cent. lead, 0.0145 per cent.=4 oz. 4 dwt. 10 gr. silver, 0.76 per cent. antimony, 0.006 per cent. copper, also blende, iron-pyrites, and a small amount of quartz. The ores are carefully dressed, and are easily smelted. The furnaces used for ore-smelting greatly resemble the Flintshire furnaces. The principal difference is, the Belgian has two fire-places, one at each end, instead of one, as at Flintshire; and the hearth, instead of being concave, as at Flintshire, slightly inclines at an angle of $0^{\circ}.2$ per meter from both fire-places toward the center. The object of the two fire-places is to economize fuel and afford a greater uniformity of temperature. The molten lead is tapped into a pot in front of one of the middle doors. The charge, 1,000 kilograms, remains in the furnace sixteen hours, whereby 400 kilograms bituminous coal are consumed in its treatment, and two workmen employed. From the above charge there results 524 kilograms silver-lead, with 0.0258 per cent.=7 oz. 10 gr. silver, and 331 kilograms dross, with 66.36 per cent. lead, 2.0 per cent. antimony, and 0.0024 per cent.=1 dwt. silver.

When the furnace is first charged the temperature is kept for about half an hour at a red heat; at the end of this time the charge is worked, with short intermissions, for six hours, the temperature being raised toward the last to a cherry-red heat. Molten lead now appears; the doors are closed, and the temperature is raised. In about four hours,

during which the ore is turned every half hour, lead ceases to flow; when powdered charcoal and lime are mixed with the charge to make it pasty, and to reduce the oxides and sulphates which have formed, the charge is heated (being repeatedly worked) for about four hours longer, great care being taken that the temperature does not rise above a certain limit, lest other metals should also be reduced. The dross is now subjected to an increased temperature for one-half to three-fourths of an hour, whereby it is agglomerated. It is then withdrawn from the furnace and smelted in a low-blast furnace, with slag from the smelting of the impure ores, dross from the lead-refining furnace, and agglomerated fumes from the condensation-chambers. It is from the latter smelting that the exhibited homogeneous hard lead is produced. The object in thus slowly roasting the ore and conducting the reaction process by a low temperature is manifold. It has already been stated that the ore contains considerable copper and antimony. The reduction of these in the comparatively low temperature is avoided, and in the first reaction period the lead is not only purer, but holds the greater portion of the silver contained in the ore, and, as the operation ceases when the lead in the dross reaches 60 per cent., the volatilization of lead is diminished, which accompanies such high temperature as the production of dross containing only 10 per cent. of lead would necessitate. The loss of lead amounts, according to the assay, to only 5 per cent. The amount of dross is great, but the combined losses, occurring both in the reverberatory and the following smelting in a low-blast furnace, is much smaller than it would be were the reduction originally carried on to a greater extent in the reverberatory furnace. In July, 1872, when the writer visited these works,* the silver was separated from the silver-lead by the zinc-desilverization process. Steam was used to oxidize the zinc and antimony. The silver-zinc dross was smelted in a shaft-furnace with iron tap-cinder. There were no products of desilverization exhibited by this company.

43. Comparative trials between the Bleyberg and English (Flintshire) furnaces have been reported by M. Cahen, and commented upon by Percy, whose comments, together with the result collected by M. Cahen, I here give. The furnace employed differed considerably in its relative dimensions, form, and in a few other particulars. The ores treated assayed 79 per cent. lead. The length of the furnace-bed was 2.7 millimeters, (8′ 10″.3,) and its mean width 2.9 millimeters, (9′ 6″.17;) the grate was 2.0 millimeters (6′ 6″.74) long and 0.5 millimeters (1′ 7″.69) wide; the width of the fire-bridge was 0.6 millimeters, (1′ 11″.62;) its height from the bed 0.3 millimeters, (11″.81;) the height of the roof from the fire-bridge was 0.3 millimeters, (11″.81.)

* The writer was neither able to obtain admittance into the desilverization-works, nor was information concerning the process to be had from the officials, therefore he is not able to give an accurate description of the process here.

RESULTS OF FURNACE TRIALS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Charge, kilograms	1,000	1,000	800	1,000	1,000	1,600	2,000	2,000
Duration of a charge, hours	9	9	9	9	12	16	16	12
Lead obtained, kilograms	627.7	560	468	477	630	1,096	1,304.4	1,036
Gray slag obtained, kilograms	153	290	225	354	223	158	310	744
Lead in gray slag, per cent	39	50	44	74	35	22	30	62
Lead in gray slag, kilograms	59.8	145	99	262	78	34.76	93	463
Direct yield of lead, per cent	62.77	56.0	58.5	47.7	63.0	68.5	65.3	51.8
Yield inclusive of lead in gray slag, per cent	68.75	70.50	70.87	73.9	70.8	70.67	69.97	74.86
Loss of lead on 100 kilograms of ore	10.25	8.5	8.13	5.1	8.2	8.33	903	4.14
Loss of lead on 100 kilograms of lead	12.97	10.7	10.3	6.45	10.4	10.5	11.4	5.2
Coal per 100 kilograms, kilograms	712	562	633	506	700	917	734	375
Labor per 1,000 kilograms of galena, francs	3.75	3.75	4.70	3.75	5.00	7.91	6.33	4.75
Smithery costs per 1,000 kilograms of galena, francs	4.80	2.00	2.40	2.00	3.20	3.20	2.40	0.80

The most favorable result recorded in the table is declared to be that in column VIII, in which the direct yield of lead from ore containing 79 per cent. is 51.8 per cent., with the production of 37.7 per cent. of gray slag, containing 62 per cent. of lead; the loss being 5.2 per cent. lead, inclusive of what is estimated to be recovered from the gray slag. The results obtained in smelting galena in the Flintshire furnace, yielding about 81 per cent. of lead by assay in the iron dish, are as follows: The direct yield was 66.9 per cent., with the production of 11.9 per cent. of gray slag, containing about 55 per cent. of lead; the loss, inclusive of what occurs in smelting the slag, is 5 per cent. The consumption of coal, however, was much less in the trial reported in column VIII than in the English trials, but then it must be borne in mind that the direct yield of lead was much smaller, and the production of gray slag much greater in the former than in the latter. From the preceding considerations it will be perceived that the Belgian trials in the so-called English furnace could not have been satisfactorily conducted, owing to deficient skill, to faulty construction of the furnace, or, as is possible, to both causes. The difference between the Belgian and English results cannot be ascribed to difference in the quality of the galena treated in the two cases, as it was similar, both being easily reducible.

44. Alphonse Bodart à Lovegrée exhibited several specimens of galena, blende, and iron pyrites.

45. The "Société Anonyme des Mines et Fonderies de Zinc de la Vieille Montagne à Liége" exhibited, in a separate pavillion, an extensive collection of articles manufactured from zinc and galvanized iron. The latter was shown in various patterns for buildings, viz, for roofing, sides of houses and moldings for ornamental purposes.

46. This large Belgian corporation was founded in 1837, and has established an immense trade throughout the world, having branch establishments in Prussia, Sweden, France, Italy, Spain, and Algiers. The value of the ore extracted from the mines near Altenberg, in 1872, was $720,000 in gold. In the mining of this, 1,600 laborers were employed. Its headquarters is in Liege, but it possesses metallurgical works near

Moresnet, (Altenberg,) Mülheim on the Ruhr, Borbeck and Oberhausen, These works employed, in 1872, 900 workmen, and produced raw zinc valued at $1,200,000, and sheet zinc valued at $800,000. The archimedean screw is now used to remove lead from the remelting-furnace. In Moresnet, the heat emanating from the distilling-furnaces is utilized by conducting it directly in a single-hearth, reverberatory, calamine-calcining furnace. By means of this economized heat, from 3,600 to 4,000 pounds of ore are calcined in twenty-four hours.

The cooling of the walls of the distilling-furnace, and the irregularities of the draught, are mostly avoided by building the calcining-furnace between two distilling-furnaces, and above the topmost row of distilling-tubes; the gases escape through a chimney about 7 meters high, whose draught is regulated by means of dampers.

The calcining-furnace of these works, in which fuel is used, has two hearths and a much greater capacity than those connected with the distilling-furnaces. The upper hearth is 7.2 meters long, and the lower, 5 meters long. Its capacity is 4,000 pounds in six hours=16,000 pounds in twenty-four hours, accompanied by a calcining loss of 27 to 30 per cent and a consumption of 824 to 880 hectoliters of coal. It is, according to the above, advantageous to combine every two distilling-furnaces with one calcining-furnace in which the escaping heat may be used. But as the quantity of ore thus calcined would not be sufficient to supply the distilling-tubes or muffles, other furnaces must be built to prepare a sufficient amount of ore.

The zinc oxide is reduced in Moresnet, Mülheim, and in Borbeck, by means of the Boëtius generator gas-furnace. It is simpler and cheaper than Siemens's regenerative gas-furnace. Its economical results are excellent, (30 per cent. of fuel being saved,) and it is easily regulated.

CHAPTER VI.

SWEDISH EXHIBITS.

CHARACTER OF ORES; PRINCIPAL REDUCING-WORKS; TREATMENT OF ORES; EXPERIMENTS ON M. LUNDIN'S FURNACE; EXHIBIT OF THE STORA KOPPARBERG COPPER-WORKS; THE KAFRELTROPS STOCK COMPANY; DESCRIPTION OF THE WORKS; EXHIBIT OF NEWLY-DISCOVERED MINERALS; COPPER EXTRACTIONS, NEW PROCESS; PROCESS ORDINARILY EMPLOYED; PREPARATION OF SULPHURIC ACID USED IN THE PROCESS; MANIPULATIONS OF THE PROCESS; PRODUCTION OF SILVER-ZINC ORES.

47. A large proportion of Sweden's ores is yearly exported to foreign countries for reduction (chiefly to England) on account of an insufficient home supply of fuel. Among the metals, copper, after iron, is of the most importance. The principal copper-mines and reducing-works are at Falun and Åtvidaberg; these have been worked since the thirteenth century.

48. As the price of fuel was yearly increasing, it was proposed to dress the ore thoroughly and combine a smelting with a wet process, viz, the poor ore, consisting of the greater part of the product from the dressing-works, is roasted with salt and then lixiviated, while the concentrated ore only is smelted. With this object in view, the "Bergwerk Gesellschaft Stora-Kopparberg" at Falun, erected in 1870–'72 an immense ore-dressing establishment. The quartzose ores are crushed and assorted by means of machinery. The copper is refined in gas reverberatory furnaces, according to M. Lundin's* construction, with Siemens's regenerator, in which wood and sawdust are burned.

49. This sawdust gas-furnace, with Lundin's condenser and Siemens's regenerator, has been introduced in iron-works in Prevali, in Carinthia, and a series of experiments, conducted by M. J. Dagmer, has led to the following conclusions, taken from the "Kärntner Zeitschrift," 1871, Nos. 4, 6, and 7. From this comparison it was conceded that Lundin's method undoubtedly is of great practical value, or, at least, applicable even under unfavorable circumstances.

49. The fluctuations in the production of gas, caused by the periodical addition of cold fuel, the varying amounts of water and ash contained in it, as well as the unequal sizes of the material used and fluctuations in the force of the blast, &c., are principally regulated by means of the heat-regulator, and the thick walls of the generator; the adoption of a common regulator for two furnaces guarantees a uniformity in the amounts of the products of distillation and a minimum in the con-

* For explanations and drawings of this furnace, see Mr. A. S. Hewitt's Report upon Iron and Steel at the Paris Exposition, p. 104.

sumption of fuel. The condensation of the carburetted hydrogen, which compound is lost in the condensation, is richly compensated by the larger production of metal, the removal of the water-vapors, the separation of alkaline compounds and of particles of coal. The only decrease of temperature, which can be looked upon as an actual loss, is that which the gases suffer by their condensation. This loss, however, is a small price to pay for the many important advantages which the work allows with purified gases, free from moisture.

Peat and all kind of forest-wood can be used to advantage. By the gasification of these substitutes for fuel, a higher pyrometrical temperature can be produced than by the direct use of a grate fire-place with good fuel, (which is of especial importance in the manufacture of steel.)

The purified gases may be conducted for a great length; in Sweden, for example, for a distance of 280 feet. The gasification process allows of further improvement.

50. The Stora-Kopparberg Copper-Works exhibited the following: ores, principally copper-pyrites, slag, unroasted and roasted matte, black copper, produced from the smelting of matte which had undergone five roastings, and refined copper, which is extensively used in the manufacture of brass. In addition to copper, which forms the principal product, there were also exhibited samples of gold, silver, lead, red ocher, copper and iron vitriol, sulphur, and sulphuric acid.

51. This company treated in 1871—

	Kilograms.
Quartzose	10,740.00
Pyritous ores	14,955.00
Total	25,695.00

In the working of this there was consumed—

	Kilograms.
Charcoal	8,083.80
Coke	3,322.35
Wood	6,880.80
Total	18,286.95

The production was—

	Kilograms.
Refined copper	754,135.5
Copper vitriol	113,600
Iron vitriol	23,982.5
Sulphur	380,000
Gold	6.52
Silver	92.365
Total	1,271,816.885

About 607 men and 39 women are employed in the mines and dressing and smelting works. They receive from $1 to $2.50 (gold) per day

52. The Kafveltorps Stock Company, Goteborg, exhibited samples of copper, zinc, and lead ores. The copper-ore, viz, copper-pyrites, assayed 4½ to 5 per cent. of copper. The lead-ore, galena, assayed 25 per cent. lead, carrying 15 to 30 ounces of silver. The silver contained 2½ to 3 per cent. gold. The zinc-ore, blende, carried 30 to 40 per cent. zinc and 10 to 16 per cent. argentiferous lead.

53. The Kafveltorps copper, zinc, and argentiferous mines and smelting-works are situated in the county of Örebro and mining-district of Nya Kopparberget, and have direct communication with Gottenborg and other ports by rail. The mines have been worked only since 1864, and have never been fully developed. It has been calculated that these mines and works would produce, being conducted rationally and worked on an enlarged scale, as a minimum, 600 tons lead and 300 tons copper, besides preparing 1,800 tons blende to about 40 per cent. zinc for exportation to Belgium. At present there are three furnaces used in calcining and smelting copper, and one for lead. These are now fully occupied, but the erection of more furnaces will follow the extension of the mining operations.

54. The following newly-discovered minerals were exhibited by this company: Wallerütt, occurs in serpentine, in the Kafveltorps copper mine. It is of the color of copper-pyrites, very ductile, and having a conchoidal fracture. Its chemical composition is $2\ Cu.\ S,\ Fe_2\ S_3+2\ Mg\ O\ (Fe\ Al)\ O_3+4\ H_2\ O$. Chalkopyrthotin occurs, in contact with garnet, in the Kafveltorps copper mine. It has a light, brass color, brittle, hardness, 3. Its chemical composition is, $2\ (Fe\ S.\ Cu\ S.)\ Fe_2\ S_3$.

55. There were also exhibited silver and zinc ores from Nasaberg in Norrbotten Län, Auriferous sand from Lundorren in Jemtland, copper-ore from Johannesberg in Nerike, and from the Sågmyre mines in Dalarne, copper-ore carrying 8 to 9 per cent. copper, none of which has up to the present time been worked; from Gladhamer mines in Kalmar Län, also specimens of copper-pyrites.

56. In the last few years wet processes have been introduced in two different works. These have proved, considering the local disadvantages, very profitable. These are the works at Wirum in Kalmar Län and Saltviken.

57. All other Swedish copper-works (with the exception of Falun, and that only partly) practice the old method, viz, smelting for copper matte, when, after repeated roasting and smelting for black copper, refined copper is produced. The process at these two works* is materially the same, and consists in crushing the copper-ore (at Saltviken, with a Blake's crusher) carrying about 3 per cent. copper; the ore is then mixed with 13 per cent. salt, and further crushed until it is not larger than 5 millimeters in diameter. After it has been dried on the top of the muffle furnace used for roasting, it is roasted twenty-four hours, when 4 per cent. salt is added, and the roasting continued for two to three hours longer; at

* From the *Berg and Hüttemanische Zeitung*, 1873, *p*. 153.

the end of this period the almost complete formation of copper chloride has taken place.

58. The sulphuric acid used in lixiviating copper chloride is obtained by passing the gases, consisting of sulphurous hydrochloric and small quantities of sulphuric acid and copper chloride, first through canals, in order that all particles, mechanically carried off, may be condensed, and then through a coke-tower, into which a small stream of water is pumped. This falls through a sieve, and in descending absorbs the ascending gases. This acid need not, for the purpose for which it is used, be stronger than 14° to 15° Twaddle's hydrometer, but is generally more concentrated than this.

59. The calcining hearth is 8.313 by 3.563 inches and 0.3 meter high. The coke-tower is built of wood, and is 23.75 meters high; at the bottom it is 3.266 by 3.266 meters; at the top, 3.12 by 3.12 meters wide. The bottom of the tower is composed of two perforated stone arches; upon the upper the coke is piled about 18 meters high; the pieces of coke are about 3.5 by 3 centimeters large. Above the tower there is a flat roof with a small chimney; under this roof is a false floor containing numerous small holes through which the water drops upon the coke. There is obtained from this tower about 1,626 liters of acid of 16° or 1.080 specific weight. As the ascending power of the gases is in proportion to the differences between their temperature and the temperature of the external air, it occurs sometimes, in summer, that the furnace draught is decreased to so great an extent that the gases return and escape through the working doors. This great objection to the process is increased by the coke being crushed by its own weight, and becoming choked by small particles carried off by the furnace draught. These latter obstacles are greatly removed by washing the coke weekly with clean water. The warm chloridized ore, after being placed in the lixiviating-tub, is first treated with hot water and then with weak acid. This solution is repeatedly poured over the mass until it ceases dissolving; then stronger acid is used, and finally acid direct from the coke-tower The residue is then washed with warm water, and, if it does not contain more than 0.1 per cent. copper, the operation is finished. One tub containing 183½ centner ore, can be perfectly lixiviated in twenty-four hours, but as the supply of tubs is greater than the demand, the ore is allowed to remain in them for four days, and the solutions passed through from 10 to 30 times. The solution containing the copper chloride is warmed, to increase its volume, by conducting steam into it.

The copper is precipitated by means of iron, wrought iron being preferred; of the latter 100 pounds is consumed to precipitate 80 pounds of copper. The quality of the iron used determines the length of time necessary in precipitation, which is from three to five days. The iron and precipitated copper are placed in a metallic sieve having holes 12 millimeters in diameter. Water is poured into the sieve and the copper falls through; the iron remaining in the sieve.

60. The expenses and production of working two furnaces for one month were:

	Thaler.*
183,720 kilograms ore cost	1,166.40
31,250 kilograms salt	198.18
617.5 kilograms wrought iron	135.00
91,800 kilograms bituminous coal for furnace } 61,200 kilograms coal for engine, &c }	972.00
Wood for drying the precipitate	1.60
Wages	237.75
	2,710.93

The production was 127½ copper precipitate, containing 80 per cent. copper, valued at 2,812.5 thaler.

To produce 1 centner copper precipitate, containing 80 per cent. copper and 20 per cent. iron and basic salts costs:

9.15 thaler for ore.
10.44 thaler for cost of reduction.

19.59 thaler.

The gain per 1 centner of precipitate is 2.47 thaler. This precipitate is exported to England.

61. Argentiferous lead is found in several places. The silver-works near Sala are the oldest and most important. Sweden does not produce metallic zinc, but it is found in large quantities at the mines near Ammeberg, which are owned by the company of La Veille Montagne.

* 1 thaler = $1.03 gold.

CHAPTER VII.

NORWEGIAN EXHIBITS.

IMPORTANT ORES; EXHIBITS OF THE ALTENER COPPER WORKS, COPPER MINERALS, ZINC AND LEAD ORES; EXHIBITS AND STATISTICS OF THE KONSBERG SILVER WORKS.

62. The mineral-metallic wealth of Norway, although considerable, is not at present sufficient to supply the internal demand. It is, therefore, necessary to supply the deficiency by importation. Its most important metallic products are copper, iron, nickel, silver, and cobalt.

63. In the year 1870 the seventy-six mines then worked employed 2,600 workmen. They produced a total of 125,800,000 kilograms of ore. Of these, twenty-seven were copper mines, employing 1,270 workmen, and producing 47,200,000 kilograms of copper-ore. The seven silver mines produced 2,200,000 kilograms of ore, and employed 363 workmen. The production of copper and silver has undergone no material change since 1865. At present there are eleven copper-works, employing 255 workmen, and producing 520,000 kilograms refined copper. Of these copper metallurgical works, those at Röras, founded in 1644, and working ore carrying 7 to 8 per cent. of copper, are the most important. The next in importance are the Altener Copper-Works, in Finland, founded in 1839, and the copper-works on the Vigsnäs, in Stavanger district. In 1871 Norway exported unrefined copper valued at 259,000 spec.,* and imported copper valued at 23,000 spec.

64. The Altener Copper-Works exhibited interesting specimens of their ores and intermediate products. These consisted of samples of refined copper, which was of a light-red color, fine, granular, and contained the following amounts of foreign substances:

	Per cent.
Cu	99. 05
Fe	0. 06
Ni	0. 085
Pb	0. 20
Mn	0. 015
Ag	0. 03
O	0. 545
Bi	trace.
	99. 985

* Spec., or speciesthaler=$1.03 gold.

Black copper, having the following composition:

	Per cent.
Cu	91.486
Fe	5.039
Co and Ni	1.507
Pb	0.454
Zn	1.046
S	0.854
	100.386

Raw matte, of the following chemical composition:

	Per cent.
Cu	19.24
Fe	49.83
Co	2.56
Ni	trace.
Pb	0.39
Zn	2.15
S	24.62
	98.79

Slag, from black copper smelting, having the following composition:

	Per cent.
$Si\ O_2$	26.00
$Al_2\ O_3$	2.69
$Ca\ O$	0.57
$Mg\ O$	2.40
$Fe\ O$	67.57
$Cu\ O$	0.44
	99.67

Slag, from ore-smelting from matte:

	Per cent.
$Si\ O_2$	31.00
$Al_2\ O_3$	9.9
$Ca\ O$	1.0
$Mg\ O$	3.70
$Fe\ O$	53.66
$Cu_2\ O$	0.42
	99.68

In addition to these, there were samples of matte which had been roasted from one to seven times.

No. 1.—From the first roasting; of a bluish-black color, non-lustrous, and on the surface hard.

No. 2.—From the second roasting; black, with spots of red (from iron sesquioxide) and green, hard and non-lustrous.

The samples from third and fourth roastings presented a similar appearance to No. 2. 1, 2, 3, and 4 were porous, on account of many large air bubbles. The products from the fifth, sixth, and seventh roastings were black, soft, easily pulverized, full of pores, and presented a non-lustrous appearance.

65. Specimens of copper minerals were also exhibited by M. Bruenech, M. Braun, M. Krohn, and "M. Fasmer & Son." The "*Jarlsberg werk, Grubeninteressentenschaft*" exhibited zinc and lead ores.

66. The Konsberg Silver-Works are the principal works in Norway, and have a very ancient origin. They were founded in 1623, and have been, since that time, with the exception of from 1805 to 1816, continually worked. Although the production has often varied, the works have, as a rule, always proved profitable. Since 1820 they have been conducted on a limited scale, in order to secure their longevity. In 1846–1860, the yearly surplus rose to 150,000 speciethaler. They employ 24 workmen, and their average production is 3,700 kilograms of silver; the total production up to 1874 being 842,200 kilograms of fine silver.

67. The large and interesting collection of vein and mineral samples were almost the same as exhibited at the Paris Exhibition. They were here displayed on a large pyramid, on the summit of which was a large piece of (a gypsum cast) argent-sulphide, surrounded with native silver, (secondary formation,) which was taken from the Koenig mine, from a depth of 500 meters, weighed 100 kilograms, and was valued at 7,000 florins. This valuable and remakable collection consisted of—

1. Piece of later vein-formation, carrying no silver, (laminated calcite and quartz,) cellular, and containing a plain impression of silver crystals.

2. Pieces of later vein-formation, with pyrites and calcite crystals.

3. Older vein-formation, richly impregnated with silver and argent-sulphide.

6. Older vein-formation, containing silver, also anthracite in the form of shot, imbedded in calcite.

7–11. Fallbänder; older formation, containing silver, and the various gangue, viz: Quartz, garnets fluorite, adular, calcite, magnetic-pyrites, pyrites, copper-pyrites, blende.

12. Cube of native silver, 2.5 centimeters in diameter, having three edges sharply crystallized, and modified by small octahedral planes, ∞ 8 ∞.0.

13. A group of beautiful cubical crystals of native silver, (about 10 by 6 centimeters large,) between which were small calcite crystals, ∞ 0 ∞.0.

14. A group (about 10 by 3 centimeters large) of cubical native silver crystals, ∞ 0 ∞.0., rising in the form of stairs; between the silver were crystals of arsenical pyrites and calcite.

15. Large mass, weighing about eight pounds, of crystallized native

silver. These distorted cubes are about 1 centimeter in diameter and 4 centimeters long, both ends being curved and tapering to a point. All of these crystals were silver white.

16. A reddish-white mass of native silver on argent-sulphide and calcite, ranging from capillary silver to 2 by 7 centimeters.

19. A remarkably beautiful crystal of stephanite, forming a sharply-crystallized rhombic table 1 centimeter high and 2 centimeters broad.

20. Reddish-white silver of secondary formation, forming a triangular mass 20 by 14 centimeters and silver glance.

21. A piece of red, white, and yellow silver, of secondary formation, containing plain impression of calcite crystals.

22. Native silver, increasing from capillary silver to 5 centimeters in diameter to 13 centimeters long. This mass is on and around calcite crystals.

23. Was a remarkable calcite crystal, 3 centimeters in diameter, in the interior of which is a piece of native silver.

In addition to these there were exhibited granulated silver $\frac{998.3}{1000}$ fine, (for jewelers, photographers, &c.,) and silver bricks $\frac{997.4}{1000}$ fine.

CHAPTER VIII.

GERMAN EXHIBITS.

GROWTH OF MINING AND METALLURGICAL INDUSTRIES; GERMANY'S METALLURGICAL RANK; EXHIBITS BY COMBINED LEAD, SILVER, AND COPPER WORKS; EXHIBITS FROM FREIBERG; PRINCIPAL ORES TREATED; CLASSIFICATION OF VEINS IN FREIBERG MINING DISTRICT; WATER-POWER AND DRAINAGE OF THE MINES; GROWTH OF METALLURGICAL WORKS; SHAFT ROASTING-FURNACES; THE FREIBERG METALLURGICAL PROCESS; EXHIBITS FROM THE HARZ; THE HARZ METALLURGICAL PROCESS; EXHIBITS OF OKER SAGER HÜTTE, JULIUS HÜTTE; PROCESS AT THE OKER SAGER HÜTTE, THE HERZOG JULIUS HÜTTE; THE MANSFIELD COPPER-WORKS; EXHIBITS AND ORES FROM UPPER SILESIA; THE TARNOWITZ LEAD AND SMELTING WORKS; PROGRESS AND CONDITION OF LEAD MINING AND SMELTING OF THE RHINE PROVINCES; EXHIBITS OF HERBST & CO.; THE STOLBERG STOCK COMPANY FOR MINING AND THE PRODUCTION OF LEAD AND ZINC; THE RHINE NASSAU SMELTING COMPANY; THE MECHERNICHER SMELTING-WORKS; THE EMS SMELTING-WORKS.

68. The illustration of Germany's extensive mineral treasures and products of her metal extraction was, on account of its completeness and judicious arrangement, unanimously conceded to be the model exhibit in Group I of the entire Exhibition.

From all the principal mining districts there were collections made by private parties, and in some instances by the government, (where the property belonged to it,) comprising geological charts, specimens of the country's rocks and minerals: from the reduction-works, ores, intermediate and final products. These exhibits, especially those of the Saxon and Prussian metallurgical works, consisted in thorough and systematic collections, admirably arranged, and accompanied by models of furnaces, statistics of production, and diagrams of the processes; thus presenting to the professional visitor an immediate and comprehensive oversight of the character, size, and progress made by the works thus represented. It was here made apparent, even to those not well informed, that Germany, the cradle of mining and metallurgical skill and science, by reason of her immense progressive strides, retains her prominence, and is to-day the home of that science needed in the advancement of this branch of industry.

69. If we study closely the cause of the success of German metallurgists, we will learn that it is owing to several advantages they possess; these are the result of many years' experience, associated with science and natural advantages. Although Karsten says "that the date of the commencement of mining in Saxony is not to be ascertained, nor is it to be determined where it first began; that we only know with certainty

that silver-ore was mined in Saxony (in the Erzgebirge) in the second half of the twelfth century, and reached a prosperous height through the immigration of Harz miners, toward the end of that century." He says, also, "that the people who overturned the Roman Empire wandered to and settled in Bohemia, Moravia, and Saxony in the seventh century, taking with them the art of prospecting for ore and the extraction of metals." As mining in the Harz (Rammelsberg mine) dates from the ninth century, it is in all probability not so old as it is in Saxony. There is little or nothing extant from which we can discover the exact manner in which the mining and reducing operations were then conducted. But Sella informs us, "that in the first book on mining-laws, which was written in Italy in the thirteenth century, there appeared numerous German technical phrases," which indicates that mining had then its principal seat in Germany. Agricola (1546) describes lead, silver, and copper extraction processes, which were conducted in a rude manner. We see that mining here has not so ancient an origin as in some other countries, but has been prosecuted with an almost untiring zeal and an energy well worthy of imitation. This industry has been, and is, fostered and protected by the different governments, not only through laws, subsidies, and loans, but also by establishing and supporting educational institutes which are directly under governmental control. Thus have science and industry been encouraged. By means of these well-regulated mining schools and academies a constant supply is maintained of educated men, who have been directly the cause of Germany retaining her position and leading other nations with her many valuable improvements.

70. It is a noteworthy fact that those localities in Germany which are in mining-districts, and in which government technical educational institutes are established, have grown to be great mining and metallurgical centers, and the progress made, and the completeness of their operations, is in proportion to the thoroughness and advancement made at those institutes of learning. There are other places in Germany where ore is very abundant, and where the commercial facilities are extensive, but here the processes are not so perfect, although the amount of bullion produced is somewhat greater. Thus experience and science going hand in hand and assisting each other to surmount the many difficulties, which constantly occur to obstruct their progress and even their movements, the natural result—success—is attained. The natural advantage of cheap labor and material, together with a good market for the products, are of very great importance and are necessary for a large business; but these without the former advantages would be insignificant, as the value of the former, without the latter, would be greatly diminished. The technical superiority and financial success of the German miner and metallurgist are to be attributed to the above facts.

71. Germany is at present in the front rank in the production of zinc; in the production of silver, second; in lead, third; England and Spain only producing a small amount more; in copper, it ranks fourth.

72. The exhibit of Group I, representing all the countries of the German Empire, was displayed in three special buildings, one of which was devoted entirely to iron. The empire was divided into several large districts. From each district the products of the mines were arranged in the center, and around these the different metallurgical products belonging to the same district were displayed. Immediately upon entering the main annex by the middle door, the visitor saw the exhibit of the five following works: The Royal Saxon Smelting-Works, at Freiberg, the Royal Prussian Smelting-Works in the Upper Harz, the Royal Prussian and Ducal Brunswick Smelting-Works in the Lower Harz, the Incorporated Mansfield Smelting-Works near Eisleben, and the Royal Prussian Friedrichshütte near Tarnowitz.

73. The four first named constitute the "combined lead, silver, and copper works" of Germany, which, induced by the mutual desire to treat foreign ores, have united, in order to be better able to conduct their operations with greater advantages to all concerned. This idea was here expressed in a mutual display, consisting in a large and systematically arranged collection of geological maps, statistics of the growth of production, charts of processes, minerals, ores, and the various metallurgical products. The center of this exhibit was formed by a four-sided pyramid. One side of this pyramid was devoted to each of the following works: 1, Freiberg; 2, Harz; 3, Mansfield; 4, Tarnowitz.

On the sides of the pyramid were hollow glass cubes. These cubes illustrated the different metallurgical processes, as conducted at the various smelting-works, the cubes being in proportion to the weight of the various intermediate and final products represented. Thus, the size of the cube containing a product, by being in proportion to the cube holding the ore and intervening products, was made to illustrate the amount of ore treated and the quantity of each product therefrom. Samples of the products from these works were arranged in glass cases on the sides of this apartment.

74. First in order are the Freiberg works. At no other metallurgical establishment in the world are to be found so many various and numerous ores for treatment as at the Royal Saxon Metallurgical Works in Freiberg, viz, the Muldner and Halsbrückner Hütten. Almost all known metals are to be found in the ores there treated, as the following exhibited products will show: Gold, from auriferous silver; platinum sponge, from the refining of gold; silver, bismuth, extracted from the litharge and test bottom of the silver-refining furnace by dissolving in hydrochloric acid and precipitation with water; soft and antimonial lead, litharge, zinc; indium, extracted from zinc-blende, containing a small percentage of this seldom occurring metal; arsenic, white arsenical glass, (ratsbane,) red and yellow arsenic sulphides, alloy of zinc and lead, lead-speiss, lead-matte, concentrated copper-matte, slags, zinc-gray, zinc-powder, lead-fumes, sulphuric acid, soda sulphate, copper-vitriol, iron-vitriol, arsenic-sulphide, from purifying the sulphuric acid; further

on, sheet-lead, pipe-wire, and shot. There was also a model of the newly-erected round blast-furnace, with small fore-hearth. These works produce from the ores treated seventeen different articles of commerce.

75. The principal ores treated are argentiferous galena and silver ores, accompanied by copper and iron pyrites and blende; they occur in gray gneiss, in the Erzgebirge. The mines are most extensively developed under and in the neighborhood of Freiberg, where over eight hundred veins, forming groups in four different zones, extend over twenty-five miles (English) in length.

76. The whole number of veins known in the Freiberg district amounts to more than nine hundred. They have been divided by von Cotta into the following four classes:

I. The noble quartz group, so called because its valuable ores consist principally of silver minerals. The vein-mass is quartz. The minerals are ruby-silver, silver-glance, native silver, fahlerz, miargyrite, polybasiate, brittle silver-ore. Associated with these, in small quantities, are iron and copper pyrites, antimony-glance, galena, blende, fluor-spar, calc-spar, iron-spar, and heavy-spar. This group contains about one hundred and fifty veins, varying from 3 inches to 4 feet in width.

II. The pyritiferous lead and zinc group; the gangue is principally quartz. The ores are argentiferous galena, blende, iron, copper, and arsenical pyrites. Associated with these in small quantities are fluor-spar, iron-spar, heavy-spar, and calc-spar. This group contains about three hundred veins, varying from 2 inches to 3 feet in width.

III. The noble lead group, so called on account of silver-ores occurring with the lead-ores. It occurs in gray gneiss. The gangue is manganese-spar, brown-spar, and quartz. The ores are rich argentiferous galena and blende; and, as rare occurrences, the following minerals are to be named: Iron and copper pyrites and a few proper silver minerals. This group contains about three hundred and forty veins.

IV. The barytic lead group, so called from the predominance of heavy-spar and fluor-spar with silver and lead ores. The gangue is heavy-spar, fluor-spar, and quartz. The ores are argentiferous galena and blende.

The following minerals occur in smaller quantities: Iron and copper pyrites, fahlerz, and proper silver-ores. This group contains about one hundred and thirty veins, varying from 6 inches to 8 feet in width.

77. The mining machinery in this district is mostly driven by water, furnished by several systems of complicated canals, which are many miles in length. The water is conducted on the surface, as well as great distances through aqueducts and subterranean canals. This is the result of three centuries of labor. By means of ingeniously conducting the water from one mine to another, it is thoroughly utilized. The mines are drained by fifteen tunnels. The government own and control both the water sources and main draining adits. The mines are furnished with water free of expense. Each

water-wheel receives 100 cubic feet per minute, or 1,008,000 cubic feet per week, which is in many cases not sufficient to drive the large and heavily laden wheels. The mining dams contain 208,000,000 cubic feet of water. As the mines are gradually becoming deeper and the water-power is, therefore, every day becoming more and more consumed in raising the mine water from the deepest parts of the mines to the adits, the demand for still lower adits has long been a rapidly growing necessity. This was foreseen by Freiherrn von Herder, who originated the idea of constructing a tunnel from the lowest surface in Saxony, situated on the Elbe, near Rothschönberg, to the Freiberg mining-district. His estimation of 3,000,000 thalers and forty-seven years to construct it, was revised by the government authorities, and a plan made by which—first, an adit 13,070.44 meters from the same point selected by von Herder, viz, Rothschönberg on the Triebishbach (a brook flowing into the Elbe) to Halsbrücke; finally to Freiberg and Brand, costing 1,300,000 thalers, and was to be finished in twenty-two years. At the completion of this main tunnel, it was proposed to extend still farther an *Arbstolln* 23,720 meters, at a cost of 1,456,000 thalers. The workings of this celebrated engineering project is so well known that a detailed description will here be dispensed with. Suffice to say, that it is calculated to strike, in the year 1876, the Rothegrube mine, (situated in the city of Freiberg,) which is also a pumping and hoisting shaft, at a depth of 122.86 meters under the present deepest adit. The whole length of this tunnel will be 4,750,564 meters; of this, 1,307,044 meters, the main adit from Rotschönberg to Halsbrücke, is being constructed by and at the expense of the government, and 3,443,320 meters of branch tunneling inside of the Freiberg district, and draining the Himmelfahrt, Junge Hohe Birke, Freidrich Erbstolln, Herzog August, Beschert Glück, Vereingt Feld, Einigkeit, and Himmelsfürst, is to be paid for by the above-named mines, together with the "District Water-Conducting Association." The expectations of the successful working of these mines in the future are chiefly founded on the Rothschönberger tunnel, which is about four times as long as the Mont Cenis Tunnel.

78. The metallurgical works at Freiberg have attained their present state of perfection only after many years of experience, assisted by the progress of science. These works date from the year 1710; before that time, nearly every mining company smelted its own ores as often as they had accumulated in sufficient quantity. The advantages for both parties of thus centralizing the reduction-works are apparent. The smelting-works make larger profits than when there were several smaller ones, but they also pay larger prices for the ore, and make considerable loans to mines that require them. This is, in most cases, equal to presenting them with money, in order to keep them in operation. The history of these works is extremely interesting; it forms several important epochs in the history of metallurgy.

79. The smelting process was greatly improved, about the middle of the sixteenth century, by the introduction of slag-hearths, (*Krummöfen.*) These were succeeded by low-blast furnaces, (*Halbhochöfen*,) in 1588.

80. In 1790, an insufficient supply of lead caused the introduction of amalgamation. This was a modification of the American amalgamation, and called the European, or barrel amalgamation. This was partially superseded by the Augustin method, (1843,) and finally by smelting the poorest silver-ores for matte, (Roharbeit.) The latter was improved by conducting the process in reverberatory furnaces. These were first introduced in 1845. In order to thoroughly utilize the sulphur in the matte by the manufacture of sulphuric acid, shaft roasting-furnaces were built in 1854, which were a modification of the English kilns, now well known as the Freiberg kilns.

81. In 1860 the present method of extracting the silver from the roasted copper-matte, accompanied by the production of copper-vitriol, was introduced. This was followed, in 1862, by the separation of silver from gold by means of sulphuric acid. In the same year the arsenic-furnaces were built.

82. *Shaft roasting-furnaces.*—In 1863 Gerstenhofer's terrace-furnaces were erected. A few remarks will be sufficient to demonstrate the value and principles involved in this important improvement.

In general they have the advantage of good utilization of the heat, saving of fuel, rapid and continual work, and satisfactory roasting.

The most important furnaces of this class that have lately been invented and improved are those of Gerstenhofer, Stetefeldt, Hasenclever, and Helbig. We can distinguish here two classes: the first, in which the necessary temperature for roasting is supported by the combustion of the sulphur in the ores; this permits of the use of the gas for the manufacture of sulphuric acid In the second class, the roasting temperature is effected by the combustion of fuel, and the gases produced cannot be employed for the production of sulphuric acid; but by the use of fuel a more complete roasting of the charge is effected.

83. The Gerstenhofer furnace, also called terrace-furnace, belongs to the first class, and is based upon the principle of the meeting of the finely-crushed ore, which is to be roasted in its descent with the heated gaseous products of combustion streaming up through the shaft of the furnace. The atmospheric air necessary for combustion enters the furnace partly from underneath the furnace, and partly through numerous holes in the front of the furnace. These are used also to oversee the process. They can be closed by means of clay-plugs, and the access of atmospheric air is regulated by opening or closing the holes. As they are situated near each bar or bridge in the furnace, they permit the removal of any agglomerated substance that forms on the bridge. With the exception of these holes, the furnaces are closed on all sides, and it is therefore possible to produce gases that are very rich in sulphuric acid

The roasting temperature is produced by the combustion of the sulphur contained in the roasting charge; and the gases, principally composed of sulphurous acid, after having passed through the purifying canals, wherein most of the arsenious acid is deposited, are conducted into the lead-chambers for the manufacture of sulphuric acid. The shafts of these furnaces are rectangular in horizontal section. They are about 5.648 meters high, 1.412 meters wide, and 0.785 meter deep. The wall is 0.628 meter thick on the long or front side, and 0.47 meter thick on the short side; they are built in a row, so that several adjoin each other. From side to side of the shaft there pass three-sided bars of fire-clay, two of which are so placed in the sides of the shaft that one of the three edges points upward, the others downward. There is a slit in the top of the furnace, through which the ore is charged, by means of a revolving feeder, in a fine stream. Immediately under this slit there is a three-sided bar, upon which the finely-crushed ore falls and then slides down on either side of its inclined surfaces. Thus falling, in this manner, from one bar to the other, its descent is retarded, and it is kept for a longer period at the roasting temperature. When the ore reaches the bottom of the furnace in a roasted state, it is free from sulphur to within 5 to 12 per cent. It was attempted to roast the ores better by building a fire-place in the side of the furnace, but this was soon abandoned. An important objection to this is, that it renders the roasting-gases valueless for the manufacture of sulphuric acid. The roasted ore at Freiberg, with 12 per cent. sulphur, is mixed with unroasted ore, so that a charge will contain about 20 per cent. sulphur, and then roasted in reverberatory furnaces. Before the ore is charged, the furnace and fire-clay bars must be strongly heated and the ore well dried; later, the ore burns of itself and keeps the furnace at the required temperature.

84. Pyritous ores, concentrated and raw copper matte, (at Mansfeld,) and zinc-blende, for the fabrication of sulphuric acid, are the principal ores and products roasted in this furnace. Ores rich in lead cannot be roasted in this furnace, on account of their agglomeration on the bars when passing through the furnace.

85. The results of roasting vary. In Lukawitz,* Bohemia, iron-pyrites, containing 35 per cent. sulphur, is roasted so that it only contains 2½ per cent. sulphur after leaving the furnace; at the Augusten Hütte, in Beul,* 5 per cent. sulphur; in Freiberg,† blendic pyritous slimes are roasted until they carry but 12 to 13 per cent. sulphur. According to Bode, blende can be so roasted as to contain only 6 per cent. sulphur. The advantages which this furnace possesses are numerous and valuable, particularly so where the manufacture of sulphuric acid is desired. The capacity of this furnace is 2,500 kilograms pyritous slimes, (Freiberg.) In Mansfeld, about 14,000 kilograms of granulated or ground matte

* Bode. "*Schwefelsäurefabrikation*" 1872.

† Kast and Bräuning. "*Freiberger Prozesse.*"

containing 27 per cent. sulphur, is roasted in twenty-four hours; 50 per cent. of the sulphur is utilized.

86. It has already been mentioned that the consumption of fuel is insignificant. The principal requisite is that the ore must be in a finely-powdered state, and, further, the powder should be as uniform in the size of its grains as possible. The cost of crushing the ore should therefore be compared with the advantages which this furnace possesses. With kilns there is the disadvantage, that the ore roasting remains in the same position throughout the operation, and with some other furnaces (Hasenclever and Helbig) the air only passes over a limited surface of the ore; but in the Gastenhöfer, the ore particles are continually changing their position, and offering new surfaces to the hot stream of air ascending the shaft of the furnace. The economical and practical results are good. They have, however, been disputed at Freiberg, where ores carrying lea l are roasted, but as they are believed to be the most desirable furnaces known, new ones are being constructed. Compressed air is not now used, the natural draught being sufficient.

87. The principal improvements have been made: First, in decreasing the metallic volatilization, by charging the ore through one opening only, and by allowing the gases to escape through four flues in the sides or corners of the furnace. In Mansfeld, the fumes are equal to about 5 per cent. of the material treated. Second, in the arrangement for emptying the furnace of its roasted charge; the best of this kind is, perhaps, a box under the receiving-chamber, in which there is an archimedean screw, which, upon being revolved, carries the roasted ore out of the furnace, the roasting-charge preventing the air from entering or escaping. This arrangement has given excellent satisfaction in Freiberg, and has been attached to all the Gerstenhöfer roasting-furnaces at that place. The first furnace built according to this system was erected in Freiberg in 1863. The first Pilz, or round-shaft furnace with widened top, was erected in Freiberg, according to a plan of Herrn Pilz. The success of these principles caused a complete revolution in the construction of furnaces in almost all metallurgical works where the shaft-furnace is employed.

88. The history of shaft-furnaces is extended and complicated. They have been at times of very simple construction, and then again were very complex. The principal variation has been in the shape and proportions of the shaft. At first the shaft was made to decrease in size toward the top in order to effect a better utilization of the heat by the more perfect penetration of the ascending gases throughout the charge; second, diminution of loss by volatilization, by condensing, as it were, the fumes in the narrow throat of the furnace; third, a loosening up of the finely-crushed ore during its descent; fourth and lastly, by means of a larger melting-zone to spare the walls of the furnace, and make a larger production possible. The extreme of this style of furnace is to be seen in Vogel's method of construction.

89. The following are the latest conclusions as regards the shape of the furnace-shaft: By widening the shaft at the top, the heat of the furnace is not so well utilized; but by the lessening of the velocity of the ascending gases and descending charge, thereby effected, the reactions taking place between them are more perfect, and, as the ascending gas-stream moves slower, and spreads throughout the widening shaft, it cools off, and, consequently, a much smaller amount of furnace-fumes are produced. The loosening up of the finely-crushed ore is hereby lost, (which is at the present day not thought to be of great consequence,) but, on the other hand, the tilting of the charge and fuel-layers is avoided, as well as the arrival of ore in the smelting-zone before its due preparation.

90. In a small smelting-zone the charge is more perfectly smelted, and, by the increase of temperature hereby effected, the slag produced is much poorer in the metals; hence, the iron water-tuyeres have, in consequence of their many important advantages, almost universally supplanted the old method of smelting with "noses." The sides of the smelting-zone are prevented from wearing away by making use of iron water-boxes to keep them cool; but it is said that the cooled smelted matter forms accretions on them which destroys the boxes, and they are such excellent conductors of heat that it is very warm for the workmen when near the furnace.

91. A furnace with widening top was first designed by Truran in 1856, for the smelting of iron-ore.

92. Alger erected, in 1859, a furnace, elliptical in shape on the inside, and having a row of tuyeres on the opposite sides; the shaft, however, was not wider at the top than below. Both had in view the better utilization of the heat and increased production.

93. In 1862, Rachette made known his method of construction. The shaft is quadrilateral in form, and widens toward the top; in each of the longer sides there is a row of tuyeres, not exactly opposite to each other, however, but alternating; and, in order that the furnace may be easily blown in during the winter time, there is a fire-place under the bed-stone, which connects with flues in the mantel-walls of the furnace. This plan of construction was intended at first for the treatment of all kinds of ore, and was, accordingly, called the "Universal furnace." This furnace was a great improvement, but it did not completely answer to all the wants of metallurgical methods of treatment.

94. The most natural and, at the same time, now most often employed construction is that of Pilz's design. They are round or octagonal, (the latter soon become round on the inside by the accretions formed,) and widen from below upward. The tuyeres were arranged about the furnace according to Sefstrom's principle. At first the shaft was made octagonal. From the level of the tuyeres up to the charging-hole, it measured 6.276 meters diameter; at the tuyeres, 1.412 meters; and at the charging-hole, 2.354 meters. It had eight water-tuyeres 0.782 meter

in diameter, and was furnished with a funnel-shaped charging apparatus. The furnace smoke and fumes were conducted away by means of a canal, and, in order to avoid explosions, this was made sufficiently large for their free escape. The shaft was enveloped within a sheet-iron mantle, which rested upon four or eight hollow cast-iron pillars. The hearth stood free; the furnace-crucible was composed of brasque. There were two cast-iron slag-spouts, three cast-iron tap-hearths, and also several slag-pots, for conveying the slag away.

95. Lately, these furnaces have been made perfectly cylindrical, 3.84 meters high and 1.726 wide. The hearth is of fire-brick, and the charging arrangement done away with. They are constructed either as crucible or hearth furnaces, with eight, and sometimes nine, tuyeres, and some are furnished with wrought-iron water-boxes.

96. These furnaces are distinguishable from all others in the following particulars, viz: they are supported by iron pillars, and stand quite alone, requiring very little space; irregularities in the smelting can be easily discovered, and access to the smelting-zone is not difficult. In consequence of these advantages, the cost of putting the furnace in readiness for smelting is small, and the smelting is conducted with little trouble. They have the form, (round,) in which the least amount of accretions form on the sides, and therefore allow of long-continued and regular smelting campaigns. The amount of fuel consumed is small, and the production of fumes not large. Slag may be produced, which carries but a small percentage of the metals. The reduction is complete, and the temperature can be increased to the point at which the melted masses react well upon each other. Covered hearths have been built immediately in front of the furnace, in order to effect an increased production. It was intended that the smelted mass should settle and separate in this fore-hearth, but, after repeated experiments, they were declared not to be effective. Heated blast, experimented upon in Clausthal in 1870, showed no advantages, as regards increased production and the forming of a slag carrying less metal, as the saving of fuel thereby effected was canceled by the consumption of bituminous coal necessary for heating the blast. In lead-ore, smelting, &c., charging-hoppers have generally been done away with, and the furnace-top is about a foot above the charging-floor, and the fumes are led off from the side.

97. At the Muldener Works, near Freiberg, about 30,000 kilograms ore, equal to 60,000 kilograms smelting-charge, are put through in twenty-four hours, with 6,000 to 7,000 kilograms of coke. At the Halsbrückner Works, about 35,000 kilograms ore, equal to about 50,000 kilograms smelting-charge, are put through in twenty-four hours, with 5,000 to 5,500 kilograms of coke. At the first-named works, the ores contain more zinc than those of the latter, so that in the treatment of blendic smelting-charges, at least 100 per cent. of slag from the same manipulation is charged with it; at the latter works, however, 50 per cent. is sufficient. The smelting-charge

is so made up that quite a large amount of matte is formed, relatively speaking, which serves at the same time as a solvent for the zinc-sulphide. The smelting campaigns at the Muldener Works last from ten to twenty weeks, and at the Halsbrückner Hütte much longer. The pressure of the blast at both works is equal to 4 centimeters quicksilver-column. The very complicated process of former years has of late become much more simplified. The ores undergo preliminary treatments, which are conducted as thoroughly as possible, and accompanied by the production of such ingredients as are of disadvantage in the smelting operations. Ores carrying such substances are treated separately, and then pass through a common smelting process. The auxiliary operations have thereby become of greater importance, especially the operation of roasting. The processes at these works are almost constantly changing, and as all the communications thereupon have been more or less imperfect, a full and detailed description of the several processes practiced at these model metallurgical works will be given. The processes at both the Halsbrückner and Muldener works are of a similar nature. The methods here described are practiced at the latter, with the exception of the copper-vitriol process and gold separation, which is conducted at the Halsbrückner Works. In addition to notes, use has been made of Herrn Kast and Bräuning's communications to the "Preussische Zeitschrift." The description of the silver extraction from roasted copper-matte is almost a reproduction of a portion of Herrn Kuhleman's communication to the same paper.

98. THE FREIBERG METALLURGICAL PROCESSES.—The metallurgical processes of Freiberg have for their main object the production of silver, gold, lead, bismuth, zinc, copper, vitriol, &c. In addition to the ores delivered by the Saxon mines in and about Freiberg, foreign and domestic ores are purchased and treated; also sweepings, or dross containing silver, lead, copper, or gold. The sulphur, present in large quantities in the greater part of the ores, is made use of as much as possible for the manufacture of sulphuric acid; some of the ores also carry a large percentage of arsenic. This is also treated to advantage in the manufacture of various arsenical products, such as arsenious acid, (ratsbane,) oripiment, realgar, and metallic arsenic. The silver contained in the Freiberg ores is more or less finely distributed throughout the ore in the form of silver-glance, stephanite, tetrahedrite, polybasite, and native silver. The lead occurs almost exclusively as galena. The copper occurs as copper-pyrites, tetrahedrite, variegated copper-ore and copper-glance. The greater part of the Freiberg ores contain, besides the metals already mentioned, unpayable quantities of gold, bismuth, cobalt, and nickel. The gangue is principally composed of calcite, bitter-spar, fluorite, baryte, and quartz.

99. *Ores.*—All ores delivered at the smelting-works are divided into two classes, viz, payable and non-payable. To the first class belong all ores that contain over a specified amount of metal, and, to the second

class, all those that do not reach this amount. For a full and official account of what ores are purchasable and what are not; the amounts paid for ores containing various amounts of the different metals, as well as the rules and regulations followed in the weighing and assaying of the same, see the translation of the "*Regulativ für den Einkauf sächsischer Erze bei den Werken der königlichen Generalschmelzadministration vom Quartal Crucis* 1868," (regulations for the purchase of Saxon ores at the works of the Royal General Smelting Administration, from the Quarterly *Crucis*, 1868.) This will be found in the appendix of this report, and, for this reason, much pertaining to the manner of weighing the ore when delivered at the works, the rules followed in selecting the assay samples, and carrying out the assays made from them, can be here omitted.

To the non-paying ores belong, 1. Dry silver-ores (*dürrerze*) containing from 0.01 to 0.04 per cent. = 2 oz., 18 dwt. 4.80 gr. to 11 oz. 13 dwt. 4.80 gr. silver; 2. Copper-ores, not containing 4.5 per cent. of silver and copper together; 3. Lead-ores, not carrying more than 15 per cent. of lead; and, 4. Nickel and cobalt ores.

100. The ores are classified, according to their composition, into the following nine classes: 1. Lead-ores, *a.* Plumbiferous ores, *b.* Galenas; 2. Copper-ores; 3. Arsenical ores; 4. Zinc-ores; 5. Sulphur-ores; 6. Pyritous silver-ores; 7. Quartzose pyritous ores; 8. Quartzose dry silver-ores; and 9. Spathic dry silver-ores. The lead-ores are all argentiferous, and compose about the half of the ores delivered at the works. They are classified into plumbiferous ores and galenas. Those containing between 15 and 29 per cent. lead belong to the first class, and those that contain over 30 per cent. lead are reckoned in the second class, (galenas.) The average percentage of lead contained in all the plumbiferous and galena ores scarcely amounts to 40 per cent., and the silver to 0.15 per cent. = 43 oz. 33 dwt. 14.40 gr. The copper-ores are also always argentiferous; they contain from 1 to 10 per cent. copper, and the general average is 3 per cent. at the highest. The delivery of copper-ores from the Freiberg mines is, comparatively speaking, very small, but at times rich foreign ores are bought. The arsenical ores contain from 10 to 40 per cent. arsenic, viz: *a.* arsenical ores, averaging 35 per cent. arsenic; *b.* arsenical pyrites, averaging 15 per cent. arsenic and 25 per cent. sulphur; *c.* arsenical lead-ores, averaging 13 per cent. arsenic and 18 to 20 per cent. lead. They are delivered over to the arsenic works. The zinc-ores, principally composed of zinc-blende, contain from 30 to 40 per cent. zinc. Lead-ores carrying less than 30 per cent. zinc are classed with the plumbiferous ores. They are delivered over to the zinc-works for treatment. All the zinc-ores carry more or less silver. All Freiberg ores that contain 20 per cent. and more of sulphur are classed with the sulphur-ores. Pyritous silver-ores are all such as are rich in silver and sulphur, and when they con-

tain 0.20 per cent. = 58 oz. 6 dwt. silver, and more, the sulphur is not paid for. They do not contain more than 1 per cent. copper, or 15 per cent. zinc. The quartzose silver-ores are poor in silver, and carry a very large percentage of silicic acid. By dry ores, (*dürrerze*,) in general, is understood all such argentiferous ores as do not contain lead and copper in payable amounts. By quartzose dry-silver ores, is to be understood all such as are principally composed of quartz, and contain only so much pyrites that they are not capable of producing 20 per cent. of raw matte by smelting. The spathic dry-silver ores are only distinguishable from the quartzose therein by the associated gangue being of a spathic, instead of silicious, nature. The classification of the ores may be simplified as follows:

1. Lead ores:
   a. Plumbiferous ores, with 15 to 29 per cent. lead.
   b. Galena, with more than 30 per cent. lead.
2. Pyrites, chiefly iron pyrites, containing not more than 15 per cent. zinc, and very little arsenic.
3. Pyritiferous ores, with 15 to 30 per cent. zinc.
4. Blende, with more than 30 per cent. zinc.
5. Arsenical ores, averaging 35 per cent. of arsenic.
6. Arsenical pyrites, with 15 per cent. arsenic and 26 to 28 per cent. sulphur.
7. Arsenical lead-ores, with 12 per cent. arsenic, and 18 to 20 per cent. lead.

The ores are also divided into stamped, jigged, and washed ores, corresponding to the manner in which they were dressed at the mines. Taken as a whole, they are called slime ores. The distinction of lump ore is also made; it is ore in pieces of about the size of a walnut.

101. *Roasting.*—Roasting has for its object the oxidation of the metallic sulphides and arsenides; and volatilization of the sulphur and arsenic to within a certain degree. The amount of sulphur contained in an unroasted charge varies from 20 to 25 per cent., and that of one having passed through this manipulation 2 to 5 per cent. The pyrites, when in lump size, are roasted in kilns, but when in a powdered condition (slimes) are roasted in Gerstenhöfer furnaces. Matte is roasted in Wellnersstalls and reverberatory furnaces, but oftener in kilns. Pyri tiferous ores are roasted in the Gerstenhöfer furnaces to 12 per cent. sulphur, then in reverberatory furnaces; and finally with residue from the zinc and coke in reverberatory furnaces. Arsenical pyrites are treated for realgar, &c. The lead-ores are mixed with the roasted pyrites from the Gerstenhöfer furnace and the ore that has been treated for realgar, when they are roasted in reverberatory furnaces to within 2 to 5 per cent. sulphur. The roasting of the lead-ore charge is conducted in long reverberatory furnaces, (*Fortschunfelungsöfen.*) These furnaces have two hearths, with the exception of two at the Halsbrückner Works, which have only one each.

102. The roasting-furnace with one hearth is of the following dimensions: Length of hearth, 48 feet; width of same, 10 feet; thus giving a roasting surface of 480 square feet. A double roasting-furnace has two hearths, one over the other, made of fire-bricks or slabs, 3 inches thick. The lower hearth has a length of 37 feet 6 inches, and is 5 feet 6 inches wide; the upper hearth is 38 feet 6 inches long and 6 feet wide. The distance from the hearth to the highest point in the arch over the same is 21 inches, with both lower and upper hearths. The lower hearth connects immediately with the fire-place and is separated from the same by the fire-bridge. A slit passes through the fire-bridge, formed by cast-iron plates; cold air constantly passing through this aperture serves to keep the fire-bridge somewhat cooler. The distance from grate to fire-bridge is 12 inches; from hearth to top of fire-bridge 8 inches. The grate is 4 feet 6 inches long and 2 feet wide. The fire-bridge is 4 feet 6 inches wide, and the distance between it and the arch is 11 inches. Both hearths connect with each other by means of an aperture 12 inches square, situated at the end opposite the fire-place. There are eight working doors connecting with the lower roasting-hearth and nine with the upper. The upper hearth has doors on both sides, the lower only on one. The lower hearth rests upon a slag-bed, covered with a layer of sand 4 inches thick; then follows a 6-inch layer of brick, and upon this come the fire-clay slabs, forming the hearth. On top of the furnace there is a drying-hearth, and in the center of the same is the charging hole, through which the roasting charge is allowed to fall upon the upper hearth. The gases from the roasting pass off from the upper hearth through a vertically-descending flue into the main canal leading to the chimney. The gases of combustion, coming from the fire-place in company with the roasting-fumes, pass from the furnace into a vertically-descending flue, and from here part of them pass into the hearth-canal and part into the muffle-canal, or into the upper and lower condensation-chambers. Both of these chambers stand in connection with a stack 150 feet high. The conducting of the fumes into two separate condensing-chambers is necessary, because, for example, if all the gases were to be first conducted into one chamber and from there into the other, they would not be large enough to hold them all. In these condensing-chambers, which are built of brick dipped in tar, are deposited all the condensable ingredients contained in the roasting gases; these are, arsenious acid, sulphurous acid, zinc-oxide, and small particles of ore. In this manner fumes are saved which are used in the manufacture of arsenious acid. The chambers are cleaned out four times in the year, after the furnaces have been burned out.

102. The fuel used in roasting is bituminous coal, from Potchappel. The daily consumption per furnace in roasting lead-ore charged, amounts to 1,800 kilograms; in roasting matte, to 800 kilograms.

103. *Modus operandi.*—Each hearth is charged with four to six charges, weighing about 750 kilograms each; when spread out the charge is about 4 to 5 inches high. Every three hours, the charge next to the fire-place,

and which is in a half-melted condition, is removed from the furnace through a door in the side of the lower hearth and flows into an iron car. This door is closed by an iron plate during the roasting of the charge. The space on the hearth hereby left empty is now supplied with the next following charge, by shoveling it from its former resting-place toward the fire-bridge. Through the aperture in the top of the furnace, a new charge is allowed to fall, after all the other charges in the furnace have been moved along one place. This operation is repeated eight times in twenty-four hours; the furnace is accordingly supplied with 9,400 cwt. of lead-ore mixture every twenty-four hours. The single-hearth furnace, at the Halsbrückner Works holds five charges, of 1,250 kilograms each. Every three hours one is removed, so that in twenty-four hours 9,600 kilograms are roasted. The operation of roasting without agglomerating the charge is conducted in the same manner. The agglomerating roasting is only employed in the roasting of lead-ore mixtures. There are three periods distinguishable in the process of roasting, viz: the commencing period, the desulphurization period, and the dead-roasting period. During the first period, which takes place on the upper hearth, the ore parts with its moisture. The charge let on to the upper hearth is allowed to remain just as it falls, without being spread out; the doors are kept closed, and it remains there until the commencement of the second period, which takes place one and a half hours later. During the desulphurization period, sulphur and arsenic are disengaged, and the ore becomes dark red. It is now necessary to stir the charge constantly, in order that every part of the same may come in contact with the atmospheric air. Sulphurous acid and arsenious acid are now disengaged in voluminous clouds. This period continues from four to five hours. During the last three hours, the dead-roasting is effected and the charge gradually ceases to evolve any more gases. The temperature must now be increased and the charge well raked, in order to free it from its last traces of sulphur and arsenic. Each furnace is attended by five men, working twelve-hour shifts. The large single-hearth furnace, however, is attended by eight men. The roasted lead-ore mixture is principally composed of the metallic oxide and basic sulphates of the metals contained in the charge, and contains per 50 kilograms 0.15 to 0.20 per cent.=43 oz. 13 dwt. 14.40 gr. to 58 oz. 6 dwt. of silver, 30 to 25 per cent. lead, 0.5 per cent. copper, 8 to 9 per cent. zinc, 15 to 20 per cent. silicic acid, and 2 to 6 per cent. sulphur.

104. The cost of roasting 1 cwt. of ore amounts to 3 silbergroschen 3 pfennige*; the items are as follows:

	Sgr.	Pf.
Coal	1	3
Wages	1	6
Repair of tools	0	6
	3	3

* A *silbergroschen* is equal to about $2\frac{1}{3}$ cents, and there are 12 *pfennige* in a groschen.

105. If a comparison be now made between the furnace with double hearth and that with one only, the latter has the advantage of greater simplicity and has less need of repairs, and, furthermore, is not inferior to the former, as far as can be judged at the present time, in the consumption of coal, labor of manipulation, and degree of roasting. The officials at the Muldener Works have expressed the above opinion, but they also, in opposition to this view, commenced a new double-hearth furnace in the spring of 1873, which was finished in the following fall. I think, were reliable data to be had, that a considerable saving of fuel would be proven.

106. It is only the American ores that are roasted in heaps or stalls. By roasting in heaps, the lump ore or product is mixed with coke and piled upon a thin layer of wood and shavings in the form of a truncated pyramid. In the center of this heap there is a chimney 8 feet high and 1 foot 6 inches wide, inside measurement. This chimney is perforated on all sides, up as high as the roasting-heap is piled around it, and is built of brick. In order that the heap may take fire more easily, there are four canals left at the base, branching out at right angles from the four sides of the chimney, and the whole heap is covered with fine coke, thus causing all the gases to find their way out through the chimney. Such a heap generally receives three fires, or, in other words, it is roasted three times. During the first fire, it burns for about four weeks; during the second, three; and during the third, two weeks. For the first fire $1\frac{3}{4}$ klafter (1 klafter = 108 cubic feet) wood and 8 scheffel (1 scheffel = $1\frac{1}{9}$ cubic feet) coke are necessary, and, after this, $\frac{3}{4}$ klafter wood and 16 scheffel coke are consumed in the roasting of 5,000 kilograms of ore or product. This operation is, at the present time, only carried out during the winter months, during which time the gases do not affect the surrounding fields so injuriously.

107. The roasting in double Wellner stalls is cheaper, but consumes more time than roasting in kilns where coal takes the place of wood for fuel. This style of roasting-stall is 32 feet long and 16 feet wide, inside measurement, and is surrounded by walls of slag-stone 7 to 8 feet high. In one of the longer sides (front) there are eight fire-places, four to each stall, standing 6 inches apart and all furnished with iron grates. The floor of the stalls rises 3 feet in its total length, rests upon crushed slag, and is built of slag-stone. Residues from the arsenical works and lead-matte are roasted in the double stalls. Both of these products have been previously roasted in kilns for the purpose of utilizing the greater amount of their sulphur for the manufacture of sulphuric acid; they consequently only require one fire in the stalls to reduce their percentage of sulphur down to 4 or 6 per cent. Lately these products have been delivered over to the operation of ore-smelting, just as they came from the kiln, without further treatment in the stalls. Lead-matte containing over 20 per cent. lead cannot be roasted to advantage in kilns for the manufacture of sulphuric acid, and is, therefore, roasted

directly in the stalls, where it is roasted in from two to three fires. The roasting-heaps in this case are never made to contain over 25,000 kilograms in order to avoid their agglomerating. In charging a stall, a thin layer of shavings is strewn on the floor, and on top of this is given another thin layer of fine coke. The product to be roasted is heaped on the fire in the form of a pyramid and the surface covered with fine coke. A stall holds from about 45,000 to 60,000 kilograms. The grate-bars are now placed within the fire-places, a fire is made, with bituminous coal, and kept up until the heap burns of its own accord. This takes from six to eight hours, and one scheffel of coal is thereby consumed. After the completion of the roasting, the heap is torn down, and the properly-roasted lumps are separated from that which is not thoroughly roasted. That which is properly roasted is distinguished by its porosity, blackish, and earthy appearance. The imperfectly roasted is generally melted together in lumps, and these lumps are broken up and roasted over again. After having received from two to three fires, this product generally contains from 4 to 6 per cent. sulphur, which is present principally in the form of sulphuric acid, in combination with the metallic oxides of iron, zinc, copper, and lead. The roasting-gases escape, through the perforated back wall of the stalls, into a canal, where they are partially condensed, and from here the remainder pass off into a chimney. About 15 cwt. of coke and 20 scheffel* of bituminous coal are consumed in roasting 1,000 cwt. of lead-matte, which has already been roasted once in the kiln; 2 scheffel of coke and 20 scheffel of bituminous coal are consumed in roasting 1,000 cwt. of roasted residues; 2 scheffel coke and 1 scheffel bituminous coal are required for roasting 500 cwt. of copper and rich lead-matte, but in the second fire 10 scheffel of coke and 2 scheffel of coal are consumed in roasting the same product.

108. THE MANUFACTURE OF SULPHURIC ACID.—The ores and metallurgical products treated for the manufacture of sulphuric acid are the following: Lead-matte, not containing over 20 per cent. lead and 20 per cent. copper; blendic pyritous, dry silver-ores poor in silver, and non-payable ores when containing 20 per cent. of sulphur or more; plumbiferous ores, containing 20 per cent. of sulphur and over, but with less than 25 per cent. lead; residues from the arsenical works that contain from 20 to 30 per cent. sulphur.

109. The ores and products are roasted in kilns and in Gerstenhöfer furnaces. All residues from the arsenical works, lump pyrites, and broken lead-matte are roasted in an English shaft roasting furnace or kiln. The general shape of the shaft is similar to the shaft of an iron blast-furnace. There are two kinds, the one larger than the other. The larger kilns, 3.14 meters high, 3.14 by 1.5 meters wide, are used for roasting substances comparatively poor in sulphur, viz, lead-matte and residues from the arsenical works; the smaller, 3.14 meters high

* 1 scheffel=190 pounds or 85 kilograms.

and 2.20 by 1.57 meters wide, for lump pyrites. On the front side, there are a number of working-doors, which are used for getting at the charge, with iron bars, in order to free the sides of the furnace from any accretions of melted matter which may have formed thereon. On the top of the kilns are charging-holes. When a kiln is to be set in work, the shaft is filled, for about two-thirds of the way up to the top, with lump-pyrites that have been roasted; a strong fire is then made on top of this, and when the furnace has become red-hot, the roasting-charge is added. This soon begins to burn of itself, and keeps the furnace at the desired temperature without further addition of fuel. After several hours the roasted ore is hauled out of the furnace, through the lower working-door, and a new quantity added. About 1,000 kilograms of matte or 750 kilograms of ore compose a charge, and about twelve hours are necessary in roasting it. In charging the kilns, the ore, or matte, is equally distributed over the whole section of the shaft. The Gerstenhöfer furnaces have already been considered. Their capacity is about 2,500 kilograms of pyritous slimes in twenty-four hours. The gases pass from the furnaces into the condensation-chamber, and from there directly into the lead-chambers for the manufacture of sulphuric acid. The system of condensation-chambers is very extensive. This is necessary, as all the pyrites, without exception, contain arsenic. There are two separate systems of condensation-chambers for the kilns and Gerstenhöfer furnaces, as the ores roasted in them are not exactly alike, and also for the reason of the large number of furnaces employed. The amount of sulphurous acid contained in the gases from the Gerstenhöfer furnaces is equal to 6 or 7 per cent. of their volume; the remainder is arsenious acid and unaltered atmospheric air.

110. Before the Gerstenhöfer roasting-furnaces came into use, the so-called "Stöckel" roasting was employed at the Freiberg smelting-works for the roasting of pyritous slimes; that is to say, the pyritous slimes were mixed with clay, and out of this mixture balls were made, and then charged into the kilns and roasted. This has been done away with altogether at the Muldener Works, and is only conducted on a limited scale at the Halsbrückner Works. By the employment of this method, pyritous slimes can be treated, which contain so much lead that it would be impossible to roast them in Gerstenhöfer furnaces, as they would agglomerate. The slimes are mixed with 5 per cent. of clay, and made into balls. This small quantity, however, would not be sufficient, if the clay were not given more consistency, by the addition of the acidulated mother-liquid from the copper-extraction process. In dissolving the argentiferous copper-matte, the mother-liquid seemed to contain a considerable quantity of iron, so that the operation cannot be repeated so often, as is possible in dissolving the argentiferous copper. The employment of this solution for the forming of roasting-balls (Stöckel) met a want greatly felt, and also made the solution of some value. The solution must be made still more acid with the addition of sulphuric

acid, so that the clay will be partially dissolved, in order to make the roasting-balls durable. The balls are well dried by the waste heat of several apparatuses; and they then roast very well in kilns to within 7 or 8 per cent. sulphur, and are roasted further in stalls only in exceptional cases. Although at the Halsbrückner Works there is plenty of boy labor to be had for carrying out the work of making the roasting-balls, still it costs 2½ silbergroschen to make a hundredweight or 50 kilograms. The condensation canals, in which the gases from the kilns and Gerstenhöfer furnaces circulate, are of considerable length, as it is of importance to free the gases, as far as possible, from the arsenious acid before entering the sulphuric acid chambers.

111. The canals are constructed of bricks dipped in tar; these withstand the effects of the sulphurous acid better than common bricks. The condensing-chambers are covered on top with iron plates, because they help to cool the gases off; also because an arch of masonry would not last long under the influence of the acid gases. Subterranean canal connections are avoided as far as possible, the draught being effected thereby; also because the moisture absorbs the sulphurous acid and destroys the masonry.

112. Lead-chambers are used for the condensation of the roasting-gases. The gases, however, do not enter these chambers until they have circulated through the ordinary canals. The lead-chambers are very serviceable in cooling off the gases. The gases enter the sulphuric-acid chambers perfectly cool by means of the arrangements above described. The lead-chambers, in which the sulphuric acid is made, are large parallelo-pipedorical compartments, surrounded on all sides with sheet-lead, which is supported by a strong frame-work of timber. A system consists of a fore-chamber and a roof-chamber. All the chambers are connected with each other by large pipes. The formation of the acid takes place in the main chamber, and the sole object of the roof-chamber is to condense the sulphuric-acid vapors. According to the new system, the fore chamber is connected with the first main chamber thereby, and this is furnished with a partition-wall on one of the shorter sides, where the gases enter. This partition reaches nearly to the floor. Formerly the nitric acid was conducted into the fore chamber. At present, however, it is led into the main chamber, where it flows over a number of large earthen dishes, so placed inside of each other as to form a sort of terrace. Steam is led into each of the main chambers from the roof, and condenses on entering the chambers, falling to the bottom as fine rain.

113. The nitric acid is produced from soda-saltpeter by treating it with sulphuric acid. The nitric acid set free is collected in a row of flasks. The decomposition of the saltpeter is conducted in a cast-iron cylinder, or, better, in a kettle of the same material, under which a low fire is kept up on the grate in the fire-place. A charge consists of one hundred and fifteen kilograms of sulphuric acid, and one

hundred and twenty-five kilograms of saltpeter. After two days the bisulphate of soda formed is removed from the kettle and the process commenced over again. The sulphuric acid is poured into the kettle through a lead funnel. In the first flasks, which are emptied by means of siphons, there is 45° to 50° acid. In the last, however, nitric acid of only 15° is generated. By mixing, an acid of 36° is obtained. Sixty-two kilograms of nitric acid are obtained from fifty kilograms of saltpeter, and forty-seven kilograms of sulphate of soda as a by-product.

114. A Gay–Lussac apparatus is used for saving the nitrous and nitric acids, which pass out from the chambers. This apparatus consists of a lead tower filled with coke, in which the nitrous acid is absorbed by sulphuric acid. The distribution of 60° sulphuric acid over the coke-tower is effected partly by a small turbine and partly by numerous stop-cocks. The former seems to do its work more effectually when it is given a little attention. Thirty kilograms of acid of 60° B. is consumed in supplying the Gay–Lussac apparatus per fifty kilograms of acid of 60° B. produced. The acid necessary for feeding this apparatus is concentrated, without previous precipitation, in a compartment underneath the lead-chambers. The sulphuric acid, with its absorbed nitrous acid, flows out of the Gay–Lussac apparatus into a boiling-apparatus. It is reduced to 50° with water and then heated; the nitrous acid is thereby expelled and conducted back to the lead-chamber. The sulphuric acid is then allowed to flow through pipes into the precipitation house, where it is freed from its impurities. In consequence of this arrangement the production of acid can be effected with a great saving in nitric acid.

115. The acid which condenses in the lead-chamber and collects on the bottom, should not be stronger than 48° to 50° B. (Specific gravity 1–5.) It is tapped off from time to time into tanks. There are dropping arrangements on the sides of the chambers by which the process of the formation of the acid in the chambers can be watched and the quantity of nitric acid and steam entering the chambers regulated. If, for example, the acid is stronger than 50° B., more steam is allowed to enter the chambers; if it is less, more nitric acid. The level of the acid in the chambers is determined by floats.

116. A chamber-system of 9,400 cubic feet capacity, can produce daily from 3,500 to 4,000 kilograms of sulphuric acid of 66° B., with a consumption of 75 kilograms of nitric acid. A system of 160,000 cubic feet can produce daily 5,000 kilograms acid with 100 kilograms of nitric acid.

117. There are three systems at the "Muldener Hütte," one of 9,400 cubic feet capacity, one of 134,000, and one of 160,000. The first system is provided with sulphurous acid by the kilns, the others by Gerstenhöfer furnaces. The normal working of the process is known by the warmth of the chamber-walls, by dropping of the acid in the drop-apparatus, and by the brown color of the escaping nitric and nitrous acids. There are two windows in the roof-chamber at its end, for the

purpose of observing the color of these gases. If the gases appear pale yellow, there is a lack of nitric acid in the chambers.

118. *Purifying the chamber-acid.*—This is accomplished by precipitating the arsenic with sulphuretted hydrogen. The sulphuretted hydrogen is produced from a raw matte, free from zinc, which is obtained by smelting raw lump-pyrites, free from all blende, with a flux of slag. This matte, principally composed of protosulphide of iron, is broken up into small pieces, and treated with diluted sulphuric acid in a box-shaped generating-apparatus. The apparatus consists of two wooden boxes, lined with sheet-lead, which communicate with each other by means of a lead pipe. There is a lead sieve, supported by bricks, several inches above the bottom of one of the boxes, which serves as a canal for the iron vitriol solution formed. The iron-matte is placed upon the lead sieve in quantities of 3,500 to 4,000 kilograms. The sulphuretted hydrogen is disengaged by sulphuric acid dripping on the matte through a W-shaped pipe, leading from the other box. If sulphuretted hydrogen should be evolved in too great quantities, the pressure produced by the same would force the sulphuric acid and iron vitriol solution into the neighboring box. The gas passes from the generating-apparatus into a washing-apparatus, which is provided with two small windows, for the purpose of observing the generation of the gas. The residue from the iron-matte is removed from the generating-apparatus after four or six weeks, and is delivered over to the ore-smelting operations, as it contains 0.10 per cent. = 29 oz. 2 dwt. silver and 3 per cent. copper. The iron vitriol solution is 28° strong. It is evaporated in lead pans until it reaches 40°, and is then brought into crystallizing-vessels, wherein the iron vitriol crystallizes on lead strips hung in the solution. The crystals are broken from the lead strips, dried, and are then ready for market.

The sulphuretted hydrogen gas, after passing through the washing-apparatus, enters the precipitation-tower. This is a chamber having the shape of a shaft, with a rectangular horizontal section, the walls of which are of sheet-lead. The whole compartment is filled with horizontal bars, having the shape of a pointed roof, the side edges of which are cut out like a saw. These beams are arranged in rows, alongside and over each other, and in such a manner that the alternating rows consist of eight and nine bars. The sulphuric acid, when led into this precipitation-tower from the top falls to the bottom in the form of fine rain; it falls from one bar to the other, and drips from off the saw-like edges. The sulphuretted hydrogen gas is conducted into the tower from below. By means of this apparatus an almost complete precipitation of the arsenic contained in the sulphuric acid is effected. The tower is fed with the sulphuric acid by means of tilting troughs, from which it flows into the tower through a lead sieve. The acid, on leaving the tower, flows into settling-tanks, wherein the precipitate of sulphide of arsenic gradually sinks to the bottom. In case the acid should not be

pure enough, it is forced up again over the precipitation-tower by means of an air-condensing apparatus; generally, however, this is not the case. The sulphide of arsenic is placed in filtering-boxes lined with sheet-lead; here the acid drains off. It is then placed in another box, which has a sand filterer in the bottom. It is then delivered over to the arsenical works for further treatment.

119. *The evaporation of the purified acid.*—This operation is conducted in lead pans, of which there are generally four or six, so placed over one another as to form a kind of terrace. Each pan is provided with a spout, through which the acid can flow. The pans are very shallow, from 12 to 15 inches deep, in order that the evaporation may progress with rapidity. The acid is evaporated until it reaches 60° B.; stronger acid would affect the lead pans. The specific gravity of this acid is 1.7, and contains 79 per cent. of 66° B. sulphuric acid. The pan nearest the fire-place is placed upon an iron plate. The acid to be concentrated is allowed to flow into the pan farthest from the fire-place, which is least under the influence of the heat, and gradually flows into the one nearest the fire. The acid vapors from the pans escape into the atmosphere. The operation is continual.

120. The further concentration to 66° B. is conducted in platinum retorts, of which there are two at the Muldener Hütte. One of these has a capacity of 20,000 kilograms, the other, of 12,500 kilograms. The 60° B. sulphuric acid is brought into the platinum-retort directly from the last pan, by means of a siphon. The retort stands over a fire-place with terrace-grate. Bituminous coal is employed as fuel. The acid-water vapors pass off from the retort through a platinum-pipe into a spiral pipe of lead, which is situated in a cooling-box, filled with water. The vapors are hereby condensed, and acid is obtained of 25° B., which is forced into the first evaporating pan by means of a small force-pump, worked by hand. The acid remaining in the platinum-retort is concentrated to 66° B., and settles to the bottom by reason of its high specific gravity. It is continually withdrawn from the retort by means of a siphon of platinum, which passes through a Liebig cooling-apparatus. The concentrated acid flows into settling-vessels, from which it is filled into glass balloons. The concentrated sulphuric acid is oily, has a specific gravity of 1.8, contains 81 per cent. of anhydrate sulphuric acid, and is of the color of water. In filling the balloons organic substances give it a brown color.

121. THE MANUFACTURE OF ARSENICAL PRODUCTS.—These products are:

1. Arsenious acid.
1*a*. Arsenical glass.
2. Sulpho-arsenics.
2*a*. Oripiment.
2*b*. Realgar.
3. Metallic arsenic.

The ores treated for the manufacture of these products are, arsenical

pyrites, arsenical lead-ores, and pyritous ores containing arsenic. They contain between 10 and 40 per cent. arsenic. Besides these, the arsenical fumes, from the operations of roasting, collected in the condensation-chambers, are treated.

122. *Production of arsenious acid.*—This is produed by the roasting of arsenical ores which contain but a small amount of iron pyrites. The principal ores treated are arsenical ores and arsenical lead-ores. The operation is conducted in an arsenic sublimation furnace which has a gas-generator attached. Each furnace stands in connection with a canal, built of brick, wherein the arsenious acid collects. The length of the canal is about 800 feet. The hearths of these reverberatory furnaces are 14 feet long and 10 feet wide; on either side are two working doors. The grate is situated about 6 feet below the fire-bridge, and is filled with coke up to the top of the latter. The gases are ignited by means of atmospheric air, which enters the furnace through special canals. With this simple furnace an arsenious acid is produced, which is perfectly white and free from all particles of carbon or coal-ash. A charge consists of 1,200 kilograms. As the escape of ore, in the form of fine dust, cannot be avoided during the charging of the furnace and working the charge, the arsenious acid canal is kept closed by means of a damper while these operations are being carried out, and the fine particles of ore escape from the furnace into the atmosphere through a special chimney constructed for that purpose. A charge is roasted in eight hours, and 6 *scheffel* * of coke are consumed. The roasted ore, containing not more than from 1 to 2 per cent. arsenic, is subjected to the operation of ore-smelting, as it contains silver and lead. The arsenious acid is sublimed in the same furnace. A charge consists of 600 kilograms, and it is sublimed in six hours; whereby from 85 to 87 per cent. of the arsenic contained therein is obtained. It is sold in this state as arsenious acid.

123. *Production of white arsenical glass.*—The arsenical ores give but a small amount of the material used for the manufacture of white arsenical glass, and are neither fitted for the production of realgar nor metallic arsenic. They contain from 18 to 20 per cent. lead and 12 per cent. arsenic. The greater part of the salable white arsenic is obtained from the fumes of the dust-roasting furnace, (Gerstenhöfer's,) kilns, and long reverberatory roasting-furnaces, part of which contains 75 per cent. of arsenious acid. The fumes from the blast-furnaces, on the other hand, are too poor in arsenious acid to be used, and therefore are put through these furnaces again. This is also done with the fumes which settle in the canals near the roasting-furnaces; they only contain a small amount of arsenious acid, but a large amount of arseniate salts and arsenic acid. In that part of the canals farthest removed from the furnaces, the fumes are colored a light red by the easily volatilized selenium, and produce a yellow glass, but after it has become hard and porcelain-like, by lying for some time, it loses its color.

124. White arsenical glass is arsenious acid which has been melted;

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* *Scheffel*, a sack, a bushel.

it forms a homogeneous mass, has a vitreous luster, and is either transparent or milk-white. Its method of manufacture rests upon the fact that arsenious acid volatilizes before it fuses. The arsenious acid is heated in cast-iron pots, which are covered with sheet-iron hoods. The pots are 23 inches in diameter and 20 inches deep. The hoods are 6 feet 8 inches high; the height of the cylindrical part is 3 feet 4 inches and 2 feet wide; the height of the conical-shaped part is 20 inches, and the upper width 6 inches. Connecting with the hood is a 6-inch pipe, which passes into the condensation-chambers. The pots stand from 60 to 70 charges.*

Iron containing but little graphite has been found to be the most suitable, as that which contains much of this substance is not so durable, and also gives the arsenical glass a dark color. This is explained by the fact that the graphite reduces the arsenious acid to the suboxide. Five pots make a system, and there are two systems opposite each other There is one workman to each row of pots.

125. Manipulation.—At 6 o'clock in the morning the pots are charged with arsenious acid, the hoods placed in position and cemented air-tight on to the pots, and the fires are then started and kept up for six hours. The temperature must be so regulated that water sprinkled upon the lower part of the hood turns into vapor immediately, but should volatilize slowly when sprinkled on the upper part. In order to watch the progress of the operation the pipe connecting with the hood does not fit tightly, and the fumes can therefore be seen between it and the hood. The fumes ascend spirally when the process is progressing in the proper manner. After the operation is finished the hoods and pots are cleaned out. A charge consists of 150 kilograms of arsenious acid, seven-eighths of which is obtained as glass. The consumption of fuel amounts to ½ scheffel of bituminous coal per pot. The residues consist principally of the metals contained in the arsenical ores, from which the arsenious acid was obtained. They are sent to the blast-furnaces for reduction.

126. *Production of oripiment.*—The artificial sulphide of arsenic (oripiment) contains less sulphur than the natural. It is produced by the sublimation of arsenious acid and sulphur. According to stöichiometrical proportions, to every 100 parts of arsenious acid there should be 73 parts of sulphur, but the artificial product receives a fine yellow color, when it contains much less sulphur than theory demands; it is therefore produced from 100 parts of arsenious acid and 1½ parts of sulphur. Each pot is charged with 125 kilograms of arsenious acid and 2 kilograms of sulphur; seven-eighths of this amount is obtained as oripiment, one-eighth escaping into the condensation-chambers. The manipulation is the same as in the manufacture of the white glass. The sulphur is placed on the bottom of the pot, and over it the arsenious acid. Different shades of yellow are made as called for by the consumers; 2 per cent. sulphur produces the color generally desired.

* Kast and Bräuning, in their paper entitled "*Mittheilungen über die Freiberg Hüttenprocesse,*" say, "that a pot will put through 150 charges before giving out." The author thinks that the numbers given in the text above are much nearer the truth.

127. *Production of realgar.*—Pyritous slimes, consisting of iron pyrites and arsenical pyrites, are operated upon for the manufacture of realgar. The different kinds of slimes are mixed with each other, so that the mixture contains about 15 per cent. arsenic and from 26 to 28 per cent. sulphur. After the slimes have been perfectly dried, they are treated in sublimation-furnaces having twelve tubes. The color of the realgar must be of a certain shade. This can be produced by subliming arsenical pyrites and iron pyrites together, or with arsenic and sulphur, or arsenical pyrites and. sulphur. When iron pyrites is heated without access of atmospheric air, it evolves from 15 to 18 per cent. sulphur; arsenical pyrites, 46 per cent. arsenic. In order, therefore, to produce 100 parts realgar, 170.4 parts of iron pyrites and 150.1 parts of arsenical pyrites must be brought together. In practice, however, equal parts of both are generally taken. It has been experimented upon to manufacture this product from arsenious acid and sulphur, but it always turns out to be too rich in arsenious acid, which disqualifies it for many purposes. The method is also too expensive, as much of the sulphur becomes oxidized by the arsenious acid.

128. At the Muldener Hütte pyritous ores are principally made use of; plumbiferous ores only when necessary. The latter destroy the clay tubes, as they agglomerate, and the lead oxidizes when they are opened, and combines with the silicic acid present.

The sublimation is conducted in tubular sublimation-furnaces, of which there are eleven at the Muldener Works. Eight are employed for the production of realgar, and three are galley-furnaces, which are used for sublimating the realgar over again. Each of the former furnaces have twelve tubes. The tubes are 5 feet long, 9 inches wide, and three-fourths of an inch thick, and have an incline toward the condensers of 1.5 inch in their length. They hold about 60 pounds of ore. The tubes must be capable of withstanding the effects of the fire and the weight of the charge. They are made of equal parts of clay and a mixture of unburnt clay and dust of fire-brick. The material must be pulverized fine to make the tubes dense. A piece of old tube is placed under each tube to protect them from the full effect of the fire. Each furnace is charged with 350 kilograms of ore and kept at a red heat for twelve hours. A furnace manipulates from 600 to 700 kilograms of ore per twenty-four hours, the consumption of fuel amounting from 450 to 500 kilograms of lignite. If the charge contains from 10 to 15 per cent. arsenic, from 38 to 65 kilograms of realgar are obtained. The glass-like realgar goes through a process of clarifying. That which has not formed glass is sublimed again in galley-furnaces. The galley-furnaces are also kept at a red heat, by which one scheffel of coal is consumed. After cooling off, the condensers are removed and the glass taken out. From a charge of 107 kilograms, 90 kilograms of realgar is produced, which is also clarified. The residues, which still contain a large percentage of sulphur, are further treated for the manufacture of sul-

phuric acid, after which they are delivered over to the ore-smelting operations. From the total amount of arsenic contained in the ores, about 86 or 87 per cent. is obtained as realgar. To every six furnaces there are four workmen, who make eight-hour shifts.

129. *Clarifying of the realgar.*—The object of this manipulation is to give the glass a homogeneous texture, and to produce the exact shade of color by the addition of sulphur. A cast-iron pot is used for this purpose, which is 16 inches in diameter and 22 inches deep. About 125 kilograms of realgar compose a charge. From 6 to 9 kilograms of sulphur are added per 50 kilograms. From one to one and a half hours are necessary to clarify the above quantity. The amount produced is equal to 100 per cent., as the loss by volatilization is about equal to the amount of sulphur afterward added. The realgar is melted in the pot, and any slag formed from the impurities of the glass is immediately removed. The workman distinguishes the color by taking out a sample. As soon as the operation is finished the molten mass is tapped off into sheet-iron vessels, which are hermetically closed until the mass has cooled. The resulting realgar contains, on an average, 75 per cent. arsenic and 25 per cent. sulphur.

130. The sulphide of arsenic, produced by the purifying of the sulphuric acid, is also treated for manufacturing realgar, but its treatment is accompanied with considerable expense and labor. The precipitate must first be freed from acid, otherwise it would not be possible to dry it. To accomplish this, the precipitate must be washed with water until it shows no acid reaction. The precipitate is then dried, and melted under pressure in closed iron retorts. This operation is necessary, because, if the finely divided sulphide of arsenic was charged into the tubes of the furnace and heated it would not produce a red glass. The mass taken from the retorts is partly treated in the galley-furnaces and partly in the tubular-furnaces, with arsenical ores and with the slag from the clarifying of the realgar. The galley-furnaces have thirteen tubes on each side. These are 24 inches long and 5 inches in diameter. With these small tubes it is possible to heat the charge gradually up to a higher temperature than can be done in the sublimation-furnaces. The resulting glass from the galley-furnaces is clarified in common with the raw glass from the sublimation-furnaces. If the raw glass obtained from the precipitate of sulphide or arsenic were to be further manipulated by itself, the resulting realgar would have a poor color. The sulphuric acid contains organic substances in solution, which are partially precipitated with the sulphide of arsenic. These substances give the glass a dark color, and would destroy the red color of the finished realgar if the latter were not principally obtained from the pure raw glass of the sublimated ore.

It will be perceived from the foregoing that the treatment of the sulphide of arsenic, obtained in purifying the sulphuric acid, is accompanied with many difficulties, and it seems to be doubtful whether this product can be treated to advantage for the manufacture of realgar.

131. *Production of metallic arsenic.*—This metal is produced from pure arsenical pyrites, or from ores that possess a large percentage of arsenic, (containing much native arsenic.) The average percentage of arsenic contained in the ores that are treated for this purpose amounts to about 35 per cent. They are delivered at the works in grape-size pieces, and charged into the tubes of the galley-furnaces for sublimation. The tubes are furnished with condensers of sheet-iron, in front of which there is a second of fire-clay, (remainder of old tubes.) The furnace is gradually heated, so that the easily volatilized sulphide of arsenic may sublimate over into the second condenser at a low temperature. After this has been effected, the temperature is increased until the more difficult volatilizable arsenic sublimes. This condenses in the first condenser, and is perfectly free from sulphide of arsenic and ready for market. The pipes are discharged after cooling off.

A charge is composed of 300 kilograms of ore, and is subjected to a white heat for eight or twelve hours. The consumption of bituminous coal amounts to between 2 and 3 scheffel, and about 25 kilograms of metallic arsenic are produced. The argentiferous residues are delivered over to the blast-furnaces for reduction.

132. PREPARATION OF THE BLENDIC PYRITOUS ORES IN REVERBERATORY FURNACES.—As has already been remarked, the zinc contained in the Freiberg ores is very troublesome to the smelting-operation in blast-furnaces. For that reason ores carrying from 15 to 30 per cent. zinc are paid less for than when they are free from this metal. Such ores as carry at least 30 per cent. zinc are designated as zinc-ores proper, and it is only these which receive payment for the blende. For this reason the mines are obliged to conduct the dressing of their ores in such a manner as to produce blendic ores payable for their zinc contents. The pyritous slimes, containing between 15 and 30 per cent. zinc, are prepared, previous to smelting in shaft-furnaces, in a peculiar manner, so that their arsenic and sulphur can be used to advantage, and zinc driven off as far as possible. These ores are first roasted in Gerstenhöfer furnaces, whereby arsenious acid is disengaged and collected in condensation-chambers, and the sulphurous acid is conducted into the sulphuric-acid chambers. The ore, after roasting in these furnaces, still contains about 13 per cent. sulphur, and for this reason is further roasted in long reverberatory furnaces. As the further manipulation rests upon the fact that almost all the sulphide of zinc is converted into oxide of zinc, the operation of roasting must therefore be carefully conducted, and as the slimes do not agglomerate, they can be so roasted that they will only contain 1.5 per cent. sulphur. The ores thus prepared are mixed with muffle-residues from the zinc-works, and coke-dust, charged into a reverberatory furnace, and smelted down with a strong fire. The manipulation is very similar to that of the concentration of the copper-matte. The reverberatory furnaces are in connection with extensive

condensation-chambers. The oxide of zinc is reduced in the furnace by means of the coke-dust, the zinc volatilizes, and is again oxidized, and passes off with the other gases into the condensation-apparatus. In this manner zinc-fumes are obtained, which are sold as paint—"zinc-gray." The fumes which settle in the canal, near the furnace, contain a large quantity of sulphate of zinc. This is dissolved out, and the residues are put back again into the furnace. The mass remaining in the furnace still contains about 10 per cent. zinc, but as its bulk has been much diminished by the separation of the sulphur and arsenic, it is probable that the greater part of the zinc formerly contained in the ore has been volatilized. Five charges per 1,720 kilograms of ore and residues are put through one furnace daily with 2,000 kilograms of coke-dust. In the manipulation of this amount 4,000 kilograms of bituminous coal are consumed. The flue of the furnace must be cleaned out at short intervals. All fumes which are not sold as zinc-gray are delivered over to the zinc-works for distillation.

133. The products of this operation are as follows:

a. Dezinckified residues: They contain from 0.01 to 0.015 per cent.= 2 oz. 18 dwt. 4.8 gr. to 4 oz. 7 dwt. 8.64 gr. silver and about 10 per cent. zinc; are equal in amount to about 50 per cent of the charge, and are further treated in the operation of slag-smelting.

b. Speiss: It contains 0.2 per cent.=58 oz. 6 dwt. silver, 2 per cent. lead, and 10 per cent. copper. It composes about 4 per cent. of the whole charge, and is further treated in the operation of ore-smelting.

c. Silver-lead: Contains from 1.0 to 1.3 per cent.=291 oz. to 378 oz. 8 dwt. 14 gr. silver, and is equal to about 0.16 per cent. of the whole charge.

d. Fumes: Assaying 0.005 per cent.=1 oz. 9 dwt. 3.84 gr. silver, 10 per cent. lead, 24 per cent. zinc, and containing 13 per cent. sulphuric acid; they amount to about 10 per cent. of the charge, and are generally delivered to the zinc-works.

134. Without going into the details of the cost of this operation, one will very easily perceive that the preparation of the zinc-ores in this manner is a very complicated and expensive process, and that the value of the products thereby produced can scarcely cover the expenses. The advantages of this method cannot be computed in money; they are not unimportant, however, as it is the intention of the officers at the works to treat in future zinc-ores in this manner which only carry 12 per cent. of the metal.

135. *Production of metallic zinc.*—The average percentage of zinc in the zinc-ores treated amounts to about 31.79 per cent. The ores are first roasted in kilns for the production of sulphuric acid, and then further roasted in long reverberatory furnaces, until they contain but from 0.3 to 0.5 per cent. sulphur. There are two Siemens regenerative furnaces for the reduction and distillation of the zinc contained in the roasted ores. There are also two gas-generators to each furnace, which supply them with the necessary combustible gases. The generators are simple shaft-

furnaces, which are filled with fuel, the gases passing through a long iron pipe to the zinc-furnaces. The zinc-furnaces have two rows of muffles, 16 in each row, which are 1.58 millimeters long, 23.5 centimeters wide, 49 centimeters high, and are composed of 1 part clay and 2 parts of a mixture of unburnt clay and dust of fire-brick. The prolongation of the muffles, consisting of the same material, are 62 to 71 centimeters long and 10 centimeters high. A charge for a furnace consists of 6,400 kilograms of roasted blende and 3,200 kilograms of a reducing agent, (lignite and bituminous coal or coke.) The production is equal to 50 or 85 per cent. of the zinc contained in the charge, which depends upon the temperature in the furnace. In the year 1871 the average was 59.43 per cent. Two gas-generators to a furnace consumed per day 38 hectoliters lignite and 6 hectoliters bituminous coal.

Products: *a.* Metallic zinc. *b.* Distillation residues; they contain from 10 to 14 per cent. zinc, and are delivered over to the preparatory operations for lead-ore smelting.

136. SMELTING PROCESSES.—It is desired in Freiberg to prepare a great variety of ores for one smelting process. In the accomplishment of this, most of the secondary substances contained in the ores are extracted as by-products viz, sulphuric acid, arsenical products, zinc, &c. The main object of the Freiberg smelting process is, to smelt large quantities of ore in a short space of time. As the ores contain a large percentage of zinc, and the charge is constantly varied, the result is a hurried process; the slag is not poor, but contains considerable quantities of metals and matte. This is, at the present time, deemed of small importance, as the slag is all resmelted. That from the upper part of the slag-pot is added to the ore-charge, and that from the lower part, which contains some matte, to the charge. The slag from the combined slag and matte smelting is mostly so poor that it is discarded. From the fact that the slag produced in the ore-smelting has the same composition as the slag added to the charge, the conclusion may be drawn that the elements of which the slag is composed are contained in similar proportions in the other material constituting the charge; and, moreover, that the action of the slag is only mechanical, inasmuch as the silicic acid and the basic oxides which are uncombined fuse quicker and form a slag much easier than if the slag was omitted from the charge. The extensive smelting-operations are in this manner facilitated, and the rich slags, which are produced in large quantities, are treated to advantage by utilizing them in the ore or matte smelting. The other processes are equally well conducted; so that the total loss in all the manipulations in lead is, according to Carnot, 19.27 per cent.; according to Beust, it was, in 1865, 15 per cent. The first-named gentleman gives the silver loss at 1.11 per cent.; the second, at 1 per cent.

137. *Smelting in blast-furnaces.*—By smelting in shaft-furnaces it is desired to reduce the roasted dry silver-ores, galenas, and plumbiferous ores, and all copper-ores carrying from one to 10 per cent. copper, and about 0.003 per cent.=8 oz. 14 dwt. 19 gr. silver; concentration of the

silver contained in the ores in the resulting lead, formation of a matte, and sometimes also of a speiss, when the ores contain nickle and cobalt; and separation of the gangue in the form of slag. The ores are mixed together in certain proportions to each other, and the mixture then composes the lead-smelting charge. At present, a smelting charge is composed of 500,000 kilograms of roasted ore, (500 tons.) The average make-up consists of 40 per cent. galena-ore, 15 per cent. plumbiferous ore, 25 per cent. pyritous ore, 5 per cent. quartzose pyritous ore, 14 per cent. quartzose ore and copper-ore, and 1 per cent. spathic ore. A large proportion of the plumbiferous, quartzose, and pyritous ores contained in this charge have been partially treated at the arsenic and sulphuric-acid works, and thus prepared for the smelting operation. The lead contents of such a charge amount, on an average, to 20 per cent., and the silver to 0.1 per cent.=29 oz. 2 dwt. The high-grade dry silver-ores are exempt from this smelting charge, but in making up the total smelting charge (ores, fluxes, and all) they are strewn in with the same. This is done in order to avoid as much loss, by mechanical means, as possible.

138. The separate heaps of ore, designated by the superintendent, are carted from the ore-magazine into the building used for making up the charges. A layer, from 1 to 1½ feet high, is made on the floor by dumping the various loads of lead-ore on the same; on the top of this comes a layer of dry silver-ore of the same height as the former, and then another layer of lead-ore on top of this. This operation is continued until all the various loads to go in the charge have been operated upon. After the charge has been thus put together, it is again worked over by cutting vertically through the layers and mixing well together. Each charge is lettered by marking with a piece of chalk on a shingle the letter by which it is to be designated; the shingle is stuck in the heap. In order to perfect the complete mixture of the charge, it is now shoveled over a cone, and all lumps are carefully crushed with the shovel and thrown again on the cone. The operation is sometimes repeated. The roasted lead-ore charge, after having been broken up into pieces about the size of a man's fist, and the well-roasted separated from that which has not been so thoroughly roasted, is transported in iron tramway-cars to the charging-floor of the blast-furnaces. At the present time, the smelting of the roasted lead-ore mixture is principally conducted in the cylindrical furnaces having eight tuyeres, the old Stolberg furnaces only assisting the former in this work, and it is now the intention to do away with these latter altogether.

139. *Ore-smelting in Stolberg furnaces.*—When a Stolberg furnace is to be blown in, a small coke-fire is built in the bottom of the shaft and kept up from one to one and a half days, or until the furnace has become well dried. The furnace is then gradually filled up to the top with coke. When the coke-column has settled down several feet, a slight pressure of blast is turned on; then a layer of slag and raw-matte is charged into the furnace. At first more coke than charge is put in, until the furnace begins to run in its normal fashion. This is done in order to prevent

the furnace from freezing. Each of the Stolberg furnaces have four tuyeres, 19 inches long, 2.5 inches in diameter in front, and 5.5 inches at the back. The tuyeres are 14.5 inches apart, and converge toward the front walls, and incline downward 1 inch to their length.

The smelting-charge for a Stolberg furnace, with four tuyeres, is from 10,000 to 12,500 kilograms of roasted lead-ore and 10,000 to 12,500 kilograms slag from the same operation. Besides these are added lead-matte from the same operation, roasted residues from the arsenical works, dezinckified residues, sublimation residues, purchased auriferous and argentiferous sweepings, lead fluxes, &c., &c. Formerly, roasted raw-matte was never left out of the smelting-charge, but latterly it has seldom been present. Since the working over of the lead-slag in reverberatory furnaces has been given up, the production of raw-matte has almost entirely ceased. This product is still sometimes produced in working the lead-slags over again in blast-furnaces, but in such small amounts, that it was necessary to find something which would take its place. This was found in the feruginous residues from the roasting of arsenical ores, zinc-ores, and dross carrying a large percentage of iron. Besides these, the roasted residues left in the kilns, after the roasting of pyritous lump ores, and also the American ores, can be used for this purpose, as they all contain a large percentage of iron. These products serve as the precipitating medium for the undecomposed sulphide of lead still remaining in the roasted ore. Of lead products only the refining dross and test bottom of the cupellation-furnace are mixed with the smelting-charge. The charge is made up in the following manner: upon the charging-floor a small layer of the ferruginous mixtures is spread, upon this comes the roasted-lead charge, then the necessary amount of limestone is strewn over the roasted lead-ore, and lastly, upon top of all, is added the necessary amount of slag, and then such argentiferous sweepings, or dross, are mixed in as is deemed sufficient. The charge, after having been made up as just described, is introduced into the furnace through the two charging-holes, situated a few feet above the charging-floor. Care should be taken in removing the smelting-charge, for the purpose of introducing it into the furnace, that it be cut down vertically, so that all the ingredients composing the same may become well mixed together. The fuel used is coke, and is received partly from the Klauenschen Grunde, and partly from Zwiekan. That from the former place contains 20 per cent. ash, and that from the latter 15 per cent.

140. The blast-furnaces receive their blast from double-acting cylinder-pressure blowers, the motive power being either steam or water. At the Muldener Works there are, altogether, four blast-engines; at the lower works there is a steam-blast engine of 20-horse power and a turbine-blast engine of 10-horse power. The former has two horizontal cylinders and the latter four vertical cylinders. These two engines supply the cupellation and lead-refining furnaces with blast. At the upper works there is a turbine-cylinder blower. These two engines supply the

furnaces with eight tuyeres, the silver-refining furnaces, and the black-smith's forge.

141. The coke and smelting-mixture are charged into the Stolberg furnace in horizontal layers, but in such a manner that the greater part of the smelting-mixture comes on the front wall and the coke on the back wall, thus making wedge-shaped layers of charge and coke alternating with each other. For every 12 to 14 trays (about 8 kilograms) of smelting-charge, 2 baskets (about 15 kilograms) of coke are added; therefore to every pound of fuel there are from 10 to 12 pounds of charge. This proportion between coke and charge depends, of course, on the manner in which the furnace is working. For example, if the furnace is in "good heat," the proportion of charge to fuel is increased; but if, on the other hand, the furnace begins to look dark through the tuyeres, and the formation of a "nose" can be perceived, the amount of fuel must be increased or the amount of smelting-mixture decreased. Smelting in the Stolberg furnaces is not a smelting with "noses," as may be inferred from the manner in which the furnace is charged. The smelting is always conducted with dark charging-holes. The slag is allowed to flow almost constantly into the slag-pots. These pots have an orifice, from 6 to 8 inches above the bottom, which is closed with a wooden plug while the slag is flowing in. When the slag-pot, full of slag, has been wheeled outside of the smelting-house, this plug is withdrawn, and the slag in the upper portion of the pot flows out on the ground. If any matte has flowed out of the furnace with the slag, it will be found in the bottom of the pot. This is a very convenient method of separating the two, though the separation, of course, is not perfect. The matte is worked over again, also the slag, as it contains about 0.0015 per cent. silver and from 3 to 4 per cent. lead. After the slag has been removed, the furnace is tapped for lead. This should never be executed until matte commences to flow out with the slag. Silver, lead, and matte flow into the tap-hearth, and there separate, according to their specific gravities. If speiss has been formed, it will be found between the lead and matte, and must be separated from the latter by the use of a sledge-hammer. The tap-hole is closed with a clay plug as soon as the lead has flowed out. During the tapping the blast is generally turned off; the matte is lifted from the lead, and the bullion found in the bottom of the tap-hearth is ladled out into molds; at the same time the assay-sample is carefully taken, after stirring the lead well together. Twice every day the blast is turned off, and the slag in the furnace allowed to run all out; the crust of slag that has formed over the top of the fore-crucible is removed, and the breast-holes are then opened. The inside of the furnace is then examined with an iron bar, and if any accretions have formed on the sides or bottom, they are removed, if possible, by means of the bar. If the charge should hang anywhere the difficulty is remeded, and the fore-crucible well cleaned. After the accomplishment of this operation the furnace is again closed, the blast turned on, and the smelting commences once more.

142. Products: *a*. Slag that stands between a monosilicate and a bisilicate, and containing a large percentage of iron; it flows easily and is of a dark-gray color; contains from 3 to 4 per cent. lead and from 0.0015 to 0.0025 per cent.= 8 dwt. 17.66 gr. to 14 dwt. 13.82 gr. silver. Part of it is used in fluxing the ore-charges, but the greater part is smelted over for itself in blast-furnaces. This operation is called the slag-smelting.

b. Lead-matte contains from 25 to 30 per cent. lead, 0.15 to 0.25 per cent. = 43 oz. 13 dwt. 14.4 gr. to 72 oz. 15 dwt. 14.4 gr. silver, and from 5 to 8 per cent. copper. It is stamped, roasted, and smelted with slag, in order to extract the lead and silver as completely as possible and concentrate the copper.

c. Silver-lead contains arsenic, antimony, iron, and copper, and from 0.50 to 0.60 per cent. = 145 oz. 16 dwt. to 174 oz. 19 dwt. 16 gr. silver; only when rich, dry silver-ores, or argentiferous sweepings, are mixed in with the smelting-charge does the silver amount to 0.80 or 1.00 per cent. = 233 oz. 16 dwt. or 291 oz.

d. Lead-speiss, containing lead, iron, copper, cobalt, and nickel.

143. The consumption of coke in the Stolberg furnace per twenty-four hours is about 40 cwt. Each furnace is tended by four workmen, who make 12-hour shifts. The shift changes morning and evening at 6 o'clock. There are one smelter, one assistant, one charger, and one slag-runner. The Stolberg furnaces are blown out four times during the year for repairs, thus making a smelting-campaign of about three months' duration.

144. The gases and fumes that escape from these, as well as the round and octagonal furnaces, are conducted through condensing-chambers into a chimney and from there escape into the atmosphere. The fumes collected in the condensing-chambers, consist of lead-oxide, arsenious acid, arsenic, carbon, and particles of ore. These chambers are cleared as often as the furnaces are blown out. The fumes contain from 0.005 to 0.01 per cent. = 1 oz. 9 dwt. 3.84 gr. to 2 oz. 18 dwt. 4.80 gr. silver, and 35 to 40 per cent. lead, and are mixed with the lead-ore roasting-charge for further treatment.

145. *Smelting in round blast-furnaces.*—There are three blast-furnaces with eight tuyeres at the Muldener Works, one of which is octagonal in form and the other two cylindrical. There are also two at the Halsbrückner Works, both round. This makes five in all at both works. The two at the Halsbrückner Works belong to the class of crucible-furnaces. At the Muldener Works, No. 1 is a round crucible-furnace. No. 2 is octagonal, and is at present a hearth-furnace, (*Sumpfofen;*) not long since it had a large fore-hearth, but as this did not give satisfaction, it was removed. No. 3 is a hearth-furnace, the hearth, however, not being so large as that of No. 2; the shaft is cylindrical. The two Pilz furnaces at the Halsbrückner Works are principally used for the smelting of ore. No. 1 at the Muldener generally runs on ore; No. 2 on ore, matte, and slag, and No. 3 is principally

used for smelting the slag. The shafts of the octagonal furnace are formed by eight walls, which are partly composed of fire-clay bricks, and partly of common bricks. The walls stand vertically from the canals in the foundation, for conducting off the moisture up to the level of the tuyeres, but from here on, up to the pipe for conducting off the furnace-fumes, they have a slant outward of 2 feet. The thickness of the walls is 10 inches, below the tuyeres 18 inches. For 10 inches below tuyeres and 6 inches above the same, the walls are built of fire-clay bricks; elsewhere common bricks have been used. The foundation is composed of the following materials: First comes a 2-foot 3-inch layer of slag; upon this an 18-inch layer of loam; this is covered by a layer of fire-clay, 12 inches thick, and then fire-bricks standing on edge form the bottom of the furnace. In order that the furnace may be easily cleaned out, the lower part only, for 7 feet above the floor, rests upon the foundation, while all above this rests upon eight hollow cast-iron pillars. The upper part of the furnace is surrounded by a sheet-iron mantel, on the lower end of which are elbow-irons, resting upon the iron pillars. The lower end of the mantel turns inward 7 inches at a right angle, and upon this projection the inside lining of the shaft is built up with brick. As the upper part of the furnace rests exclusively upon the eight iron pillars, the lower part can be repaired without disturbing the upper part of the shaft. In the center of each of the surrounding walls, and 4 feet above the floor, cast-iron water-tuyeres are brought in, and are so pointed that the blast from the different tuyeres will cross at a point a little in front of the center of the shaft. The blast is conducted around the furnace in a large cast-iron pipe, and is supported by the eight iron pillars. From this main pipe eight elbow-pipes branch off, conducting the blast into the tuyeres. At the top of the furnace there is a charging-funnel, which can be closed by means of a hollow iron cylinder. The sides of the funnel have an inclination of 25°. Below this funnel there is an iron cylinder, hung in the mouth of the shaft, with a diameter of 5 feet 9 inches. Through this hollow cylinder, the smelting-charge and fuel pass into the furnace-shaft, and there spread out through the whole width of the same. In the space between this cylinder and the sides of the furnace-walls, the gases and fumes collect and pass out through an iron pipe, 3 feet in diameter, into the condensation-chambers. The furnace is furnished with two slag-spouts, which are hollow, and through which water continually circulates. There are three tap-holes, situated at equal distances from each other about the furnace, and below each of them are conical shaped cast-iron tap-hearths sunk into the floor. The following are the principal dimensions:

	Feet.	Inches.
From center of tuyeres to bottom of hearth	2	0
From center of tuyeres to the charging-funnel..........	23	3
From center of tuyeres to center of gas-conductor	20	6
Diameter of shaft at the level of the tuyeres	5	6
Diameter of shaft at the gas-conductor.................	7	6

146. The blowing in of this furnace must be conducted with the utmost care, if the immediate formation of salamanders is to be avoided. After it has been warmed for thirty-six hours, about 1,500 kilograms of lead-ore are placed in the hearth, through an opening left above the tymp-iron. This will prevent the formation of accretions. After the lead has been placed in the furnace, the hole over the tymp-iron is bricked up, and the furnace is filled with coke up to the point where the iron mantel commences. A slight pressure of blast is now turned on. Small quantities of the smelting-mixture are then added and gradually increased until the furnace smelts its customary charge. A charge made up for blowing this furnace in is generally composed of:

	Kilograms.
Slag from the smelting of lead-ore	15, 000
Lump pyrites	500
Lead-matte	500
Fluor-spar	500
Dross from lead-refining furnace	500

147. The average charge for this furnace in September, 1873, and the amount smelted in twenty-four hours were:

	Kilograms.
Slag from ore-smelting	15, 000
Slag from same operation	15, 000
Slag from concentrating copper-matte	3, 000
Roasted lead-matte	4, 000
Raw copper-matte	1, 250
Roasted pyritous ore, (containing silver)	3, 500
Cupel hearth	1, 500
Litharge	10, 000
Dezincking residue	1, 500
Limestone	1, 200
Coke	5, 550
Total	61, 500

Products: *a.* Silver-lead, 9,430 kilograms; *b.* Lead-copper matte, 3,250 kilograms, with 25 per cent. copper; *c.* Slag, with 30 to 34 per cent. silicic acid and 1 to 2.5 per cent. lead.

The pressure of the blast, when the furnace is running on full charges, is 4 centimeters of mercury.

148. The cylindrical furnace is not as high as the octagonal furnace, and the diameter of the shaft is the same throughout. In one, the gases are conducted away from the furnace, above the charging-funnel, through a 3-foot pipe, into condensation-chambers; in the others, they enter a 3-foot pipe 2 feet below the charging-floor. The distance from bottom of furnace to center of tuyeres is 2 feet; from that point to the charging-hole, 13 feet 2 inches. In making up the smelting-charge, the formation of an easily smelting and basic slag is constantly kept in

view; for this reason an acid flux is never added, but under some circumstances basic fluxes are, such as limestone and fluor-spar. The zinc contained in the Freiberg ores is the most troublesome element which they carry. In order to effect a good smelting, the amount of slag-forming flux added must be increased with the increase of zinc in the ore, and, at the same time, the smelting-charge must be so made up that considerable matte may be formed, as the matte, as well as the slag, acts as a solvent on the zinc. This explains why roasted and unroasted matte help to compose the charge at one and the same time; and, furthermore, why at the Holsbrückner Works 50 per cent. of slag is sufficient, while at the Muldener Hütte 100 per cent. is necessary; for the ores delivered at the latter works always carry more zinc than those of the former. This also explains why the furnaces with eight tuyeres work better at the Holsbrückner than at the Muldener Works.

149. The dissolving action of slag and matte on zinc-sulphide has not as yet been theoretically explained; it may be that it is in part mechanical and in part chemical. The above remarks will serve to explain the composition of the smelting-charges at the two works, which are composed about as follows:

	I. Muldener Works.	II. Holsbrückner Works.
	Kilograms.	*Kilograms.*
Roasted ore (17.6 per cent. Pb, 0.6 per cent. Cu, and 0.109 per cent. of Ag)	100	100
Raw-matte	15	3.0299
Lump pyrites from the kilns	15	.....
Slag from the same operation	80 to 100	50
Dezincking residue	.....	3.338
Fluor-spar	.....	0.3517
Limestone	.....	1.5827
Heavy-spar	.....	0.1453

The charge I is that of furnaces working in their normal state; the II is the average for a long space of time.

150. About 25,000 to 30,000 kilograms of ore = 55,000 to 70,000 kilograms of charge, are smelted in twenty-four hours in the Pilz furnace at the Muldener Works; at the Holsbrückner Works, about 35,000 kilograms of ore = about 50,000 kilograms of smelting-charge. One kilogram of coke carries from 10 to 11 kilograms of charge = 4.5 to 7 kilograms of ore. The furnaces are worked with a blast from 1-inch mercury-column.

A furnace produces: *a*, from 1,000 to 8,000 kilograms silver-lead per twenty-four hours, which contains from 0.50 to 0.60 per cent. = 145 oz. 16 dwt. to 174 oz. 19 dwt. 16 grs. silver; and *b*, 6,250 to 7,500 kilograms of matte, assaying from 0.15 per cent. to 0.20 per cent. = about 45 oz. to 49 oz. in silver, 0.15 per cent. lead, and 8 to 12 per cent. copper; *c*, the slag contains from 0.0025 to 0.005 per cent. = 14 dwt. 13.82 gr. to 1 oz. 9 dwt. 3.84 gr. silver.

A Pilz furnace is attended by a smelter, two chargers, and three slag-runners.

The following analyses will serve to show the general composition of the slag resulting from smelting the ores:

Holsbrückner Works.		Muldener Works.	
SiO_2	31.15	SiO_2	27.2
FeO	41.31		
ZnO	7.85	ZnO	10.1
Al_2O_3	3.18		
CaO	6.45		
MgO	1.06		
BaO	3.58		
MnO	2.10		
PbO	1.47	PbO	5.7
Cu_2O	0.16		
S	1.86		
	100.17		

(Muldener Works:) The other substances were not determined; the average amount of iron in the slags is given at 40 per cent.

The reasons for the economy in fuel are undoubtedly the large capacity of the furnaces and the presence of pyritous ores in the smelting-charge, which serve to form a very fusible basic slag, rich in iron.

151. Liquation of silver-lead.—Silver-lead, produced from cupriferous ores, passes through an operation of liquation for the purpose of removing some of the copper it contains previous to its treatment in the reverberatory refining-furnaces.

The liquation furnace consists of a fire-place and an inclined hearth. At the lower end of the hearth there is a deep cavity, into which the liquated lead flows as fast as it is melted. The furnace is charged with the silver-lead, and under the influence of a low temperature the lead melts and flows down along the hearth, collecting in the cavity at the lower end, leaving an unmelted residue on the hearth, which is principally composed of an alloy of lead and copper. When the lead-receptacle, in the fore part of the furnace, becomes full, the furnace is tapped, and the lead flows out into molds placed about the front of the furnace.

152. Products: *a.* Liquated silver-lead, which is delivered over to the reverberatory lead-refining furnaces.

b. Dross, containing copper, which is reduced in blast-furnaces.

c. Lead, which has already been refined, is also passed through the liquation-furnace, when the copper it may contain has not been thoroughly eliminated by the process of refining.

153. *Refining of the silver-lead.*—This operation consists in the gradual melting down of the silver-lead in reverberatory refining-furnaces and the elimination of its impurities, such as arsenic, antimony, copper, and iron, by a process of gradual oxidation.

The operation of lead-refining is conducted in reverberatory furnaces

resembling the English reverberatory smelting-furnaces. On one of the longer sides of the furnace there is an opening, which can be closed by means of a fire-clay slab. This is used for charging the furnace with lead. The fire-door is on the same side, and on the opposite side is situated the tap-hole. The working-door is in the front side of the furnace, opposite to the fire-bridge. The hearth is concave, and is supported by pillars of masonry below the floor of the refining-house. Just above the pillars, and resting upon them, are iron plates; there is a layer of loam 2 to 4 inches thick resting on the plates, and, lastly, the hearth proper, which is composed of a mixture of unburnt fire-clay and fire-brick dust, 14 inches thick. On either side of the fire-bridge there is an opening for the reception of the blast-nozzles. The nozzles connect with the blast-pipe by means of leather hose. Immediately in front of the tap-spout there is a cast-iron shallow pan hung from the ceiling and revolvable on a pivot. The lead flowing out of the tap-hole when the furnace is tapped, runs into this iron pan, and from it, through an iron spout, connected with the same, into the molds placed in a semicircle about the side of the furnace. As soon as one row of molds has become full, the pan, with its spout, is turned so that the lead will flow into the next row. This is a very convenient arrangement and does away with all ladling.

154. Bituminous coal is burned in the furnaces with shallow hearths, or lignite in those of deeper hearths. In refining 250 to 300 cwt. of lead in 24 hours, 12 cwt. of each of the first kinds of fuel are consumed, 3 to 4 cwt. of the first and 9 cwt. of the second, while only 6 cwt. of the latter sort is necessary.

155. Manipulation.—The silver-lead is charged into the furnace by means of a charging-iron; this accomplished, the charge is melted down at a low temperature. During the melting down of the charge, combinations of lead, copper, and arsenic, with antimony, are formed and rise to the surface. They are removed from the furnace through the working-door, by means of an iron rabble. The temperature is now increased to a dark-red heat, and the blast turned on. Thereby the greater part of the arsenic and antimony become oxidized, and also a small quantity of lead, and form a very fusible slag-like mass, called abstrich, which is removed by means of a green piece of wood fastened on crosswise to a long iron rod. As soon as a fine film of yellow litharge has formed over the surface of the lead the operation is finished, and the furnace tapped, after the fire has been allowed to burn feebly for about the space of one hour. If the lead is well refined it is very ductile, tough, and is of a fibrous texture on fractured surfaces. After each tapping the hearth of the furnace must be repaired with a mixture of one part clay and one part chamotte, (a mixture of unburnt fire-clay and fire-brick dust,) both of which should be finely crushed and slightly moistened.

156. Products: *a.* Refined silver-lead, which is delivered over to the Pattinson works for desilverization; or if it still contains too much cop-

per to be properly treated by this process, it is sent to the liquation-furnace.

b. Abstrich in the form of powder: About 3 per cent. of the lead put into the furnace comes out in this shape. It contains from 4 to 5 per cent. tin, and for this reason it is melted over again in the refining-furnace, with 1 to 1½ per cent of lignite, whereby lead results, which is refined, and abstrich, containing from 11 to 18 per cent. tin. It is reduced in shaft-furnaces.

c. Abstrich: It is divided into three classes. The first class is that which forms directly after the removal of the first dross (abzug) formed. It composes about 4 per cent. of the total charge. It is this abstrich which contains the most antimony, (about 12 per cent.,) and is used for the manufacture of antimonial lead.

d. Abstrich No. 2: Composes about 5½ per cent. of the total lead-charge, and contains from 5 to 6 per cent. antimony. It is delivered over to the blast-furnaces for reduction, and is yellower than that of the first class.

e. Abstrich No. 3: Is principally composed of lead-oxide, and contains only 2 per cent. antimony; is equal to about 6 per cent. of the total charge, and is of a beautiful yellow color. This is also reduced in the blast-furnaces.

157. *Production of antimonial lead.*—The material employed for the production of antimonial lead is the abstrich No. 1, already mentioned, and which contains about 12 per cent. antimony, 6 per cent. arsenic, and 2 per cent. copper. It is melted down in the lead-refining furnaces with 2 to 3 per cent. of fire-coal, and the entangled silver-lead, as well as the uncombined lead-oxide contained in it, settles down on the bottom of the hearth and is separated from the abstrich in the following manner: The melted abstrich is removed from the furnace through the working-door and the silver-lead is tapped off into molds.

158. Products: *a.* Desilverized abstrich, containing 0.001 per cent. = 5 dwt. 19.68 gr. silver, 15 per cent. antimony, 10 per cent. arsenic, and 11 per cent. copper. It is reduced in blast-furnaces.

b. Silver-lead, which is delivered over to the Pattinson works for desilverization.

159. In the reduction of the abstrich, 5 per cent. fluor-spar and 25 per cent. poor lead-slag are added as fluxing material. The reduction is conducted in Stolberg blast-furnaces. The resulting antimonial lead contains about 0.001 per cent. = 5 dwt. 19.68 gr. silver, 15 to 18 per cent. antimony, 3 per cent. arsenic, and 0.4 per cent. copper. This product passes through the liquating-furnace. The slag carries 10 per cent. of antimonial lead, and is therefore resmelted with 25 per cent. lead-slag and 5 per cent. fluor-spar, whereby an antimonial lead is obtained, which is delivered over to the ore-smelting. The liquation of the antimonial abstrich and slag-lead is conducted in a refining-furnace at a very low temperature in order to extract the copper as thoroughly as possible.

Pieces of wood are laid upon the hearth of the furnace, and upon these the antimonial lead to be treated is placed, then a layer of fuel is thrown on top of the lead. If a fire be now built in the fire-place of the furnace, the antimonial lead melts, trickles down through the pieces of wood on to the hearth and flows out at the tap-hole. It contains 15 per cent. antimony, 2 per cent. arsenic, and 0.25 per cent. copper, and is then taken to the Pattinson works, where it is poled in an iron kettle. The dross from the liquated antimonial lead remains in the furnace, and contains 4 per cent. antimony, 4 per cent. arsenic, and 1 per cent. copper. It is fluxed with fluor-spar and reduced in a shaft-furnace. The poling of the antimonial lead decreases the amount of arsenic and copper which it contains, the arsenic being volatilized and the copper oxidized during the operation. The operation is conducted in a Pattinson kettle. The charge is melted down at a low temperature, and the dross forming on the surface is removed. Pieces of green birch and pine wood are then immersed in the molten bath and held there by a lever arrangement. The moisture and gases evolved from the green wood cause the lead to boil and bubble energetically, thus continually offering fresh surfaces of the lead to the action of the atmospheric air; the copper becomes oxidized and the arsenic is volatilized. After sixty or eighty hours the kettle is emptied. A sample of the antimonial lead should have a fine granular texture on a fractured surface, and a smooth, polished surface. It contains 1.3 to 1.8 per cent. arsenic, 0.17 to 0.4 per cent. copper, and 12 to 18 per cent. antimony.

160. *The Pattinson process.*—The Pattinson kettles are of cast iron, are 5.5 feet in diameter, 3 feet deep, and have a capacity of 12,500 kilograms lead. They are from 2 to 3 inches thick on the bottom, and at the upper edge only 1.5 to 2 inches. Sixteen kettles compose a battery. The kettles at the ends are called the poor-lead kettle and the rich-lead kettle. The flange of the kettle is a separate casting and sometimes consists of two pieces. The kettles are supported by the kettle-walls, which are 20 inches high above the floor. Under each of the sixteen kettles there is a separate fire-place. Bituminous coal is used as fuel. The flames play upon the bottom and around the sides of the kettles and then pass off into a chimney, which is generally common to two fire-places.

161. Manipulation.—The manipulation is always conducted according to the two-thirds system, with or without the removal of intermediate crystals. The manipulation without the removal of intermediate crystals, is as follows: As soon as the lead in the kettle has been melted down, and the dross formed on the surface removed, the hot coals in the fire-place underneath the kettle are raked out and the fire-door left standing open, so that the cold air may enter. The lead in the kettle is then further cooled off by carefully sprinkling water over its surface; the solidified crusts which form around the edge of the kettle are broken off, thrust back into the bath, and the whole well stirred together, in order to produce a more uniform cooling. Crystals now

begin to make their appearance; they are ladled out by means of a long perforated ladle and placed in the next kettle. These crystals are octahedrons, modified by the cube. Two workmen sink the large perforated ladle into the lead, pass it along the bottom of the kettle, then bear down with their entire weight on the end of the long handle and lift the crystals out of the kettle. A block of lead placed upon the edge of the kettle serves as a fulcrum for the ladle. The ladle is then shaken in order that the mother-liquid may flow off the ladle back into the kettle; the ladle is rested upon the kettle's edge, the handle upon an iron, which inclines toward the neighboring kettle; the ladle then is lifted, and, sliding down into the next kettle, the crystals are deposited in the latter. The crystals melt immediately in this kettle, and any crust which solidifies on the edges is immediately broken off and thrust back into the liquid. In this manner two-thirds of the kettle's contents are ladled over into the neighboring kettle, and the mother-liquid left behind is ladled over into the next kettle, in the direction of the rich-lead kettle.

162. In the two-thirds system, with the removal of intermediate crystals, the crystals are ladled over into the kettle on the poor-lead side. The mother-liquid is allowed to crystallize again, and the crystals (two-thirds of the whole) are ladled over into the kettle on the rich-lead side, and the last remaining third is removed into the second kettle on the rich-lead side. In the second kettle intermediate crystals are always formed when they are worked from the first kettle into the second.

163. The resulting poor lead should never contain over 0.001 to 0.0018 = 5 dwt. 19.68 gr. to 10 dwt. 11.66 gr. silver; the rich lead, on the other hand, should contain 1.50 to 1.80 per cent. = 436 oz. 16 dwt. to 524 oz. 6 dwt. silver. The latter is delivered over to the cupellation-furnaces for further treatment, and the former is ready for the market.

164. Each kettle contains lead carrying a certain amount of silver, and to the same only lead containing a like amount of silver is ever added. In the second kettle, for example, containing lead assaying from 0.5 to 0.6 per cent. = 145 oz. 16 dwt. — 174 oz. 19 dwt. 16 gr. silver, only refined silver-lead would be added. An average assay sample is taken from each kettle after the removal of the dross, in order to keep the run of the operation and to avoid all irregularities.

165. At every kettle there are two workmen; they make three crystallizations within twelve hours' time. A fireman attends to the fires according to the directions of the foreman.

165. Products: *a.* Pattinson dross. Of three kinds, distinguished by their silver-contents; that from the first to the third kettles composes the first sort; that from the fourth to the ninth kettles composes the second sort; and that from the tenth to the fourteenth composes the third sort.

b. Rich lead, containing from 1.50 to 1.80 per cent. = 436 oz. 16 dwt. to 524 oz. 6 dwt. silver. It is cupelled.

c. Poor lead, (soft lead,) containing from 0.001 to 0.0018 =5 dwt. 19.68 gr. to 10 dwt. 11.66 gr. silver, 0.05 per cent. copper, 0.12 to 0.15 per cent. iron, and a trace of arsenic and antimony.

166. *Cupellation of the silver-lead.*—The foundation consists of gneiss, and projects 2 feet above the floor of the cupellation-house; it is provided with two canals that cross each other at right angles in the center, which serve to carry off any moisture that may collect in the foundation. The foundation supports the main crown of the furnace, which is built of sandstone or bricks, and is well anchored. In this main crown there are numerous small holes which lead in toward the center of the furnace; they serve as escapes for moisture. Upon the main crown there is a second smaller one built of brick, and in it are the litharge passage and charging-door. The litharge flows out of the former as fast as it forms. It is near the fire-place, so that the higher temperature at that place may assist to keep the litharge in a fluid state. The litharge-passage is lined with iron plates, and underneath is the iron breast-plate of the hearth. The cupellation-hearth is composed of, first, a layer of finely-crushed slag; second, a layer of fire-bricks, or a composition of quartz and clay, scooped out so as to form a concave surface; and, third, the cupellation-hearth proper, consisting of infusible marl. The hearth is covered by a movable hood of iron. The lower surface of this hood is lined with a composition consisting of two parts of quartz and one part of clay. This iron hood is hung on a revolvable crane, and can be swung away from over the hearth, so that the workmen can stamp on the hearth. In order to effect a good draught, there are sheet-iron chimneys over the litharge-passage and charging-door, which also serve to carry off the lead-fumes into the condensation-chambers. On the side opposite the litharge-passage there are two tuyeres which supply the furnace with the necessary blast for oxidation. The tuyeres are placed horizontal, but converge toward the center of the hearth. Opposite the charging-door is the fire-box, separated from the hearth by a fire-bridge, which is covered by an arch of fire-bricks. The blast escapes from nozzles in the tuyeres, which connect with the main blast-pipe by means of leather hose. These nozzles can be inclined so that the blast will strike the surface of the lead, which is not always on the same level, throughout the operation.

167. The hearth of this furnace is made of calcareous marl, which is principally composed of carbonate of lime and silicate of alumina. For the preparation of this marl, 8 cwt. of fresh and 1 cwt. of already-used marl is employed, and also $\frac{1}{2}$ cwt. of clay. All this material is well mixed together until it possesses consistency; the marl and clay are finely pulverized, sieved, and moistened with water, so that the mass will ball in the hand without leaving moisture on the same. This mixture must be infusible, should not act as a reducing agent on lead-oxide, and must possess a certain porosity. This mixture is stamped upon the hearth in the following manner: The necessary amount of the composition is

placed in the furnace and stamped upon the hearth in such a manner as to form a concave surface. For the purpose of collecting the remaining amount of plumbiferous silver, which also contains bismuth, the deepest point of the hearth is made near the charging-door, so that it may be ladled out into cast-iron molds, when the operation is finished.

168. After the test has been properly stamped on the hearth of the furnace, the silver-lead to be cupelled is placed within the furnace, without any previous heating of the hearth; the lead is placed carefully upon the hearth with the hand; the hood is swung back from the furnace during this operation, also while the hearth is being stamped in; the hood is swung back again over the hearth when 8,750 kilograms of silver-lead have been charged, and all crevices between the same and the furnace are then stuffed with loam.

169. Manipulation.—Wood is now placed upon the lead and set on fire; a small wood-fire is also kept up in the fire-place until the lead has become melted. It takes from twenty to twenty-four hours to melt down the entire charge. The moisture in the test now escapes through the holes in the main crown of the furnace. If the fire should be too strong, there is danger of cracks forming in the hearth, in which case it would have to be renewed. During the melting-down of the lead charge a slight pressure of blast is allowed to enter the furnace, in order to support the combustion of the wood. Sheet-iron hoods are placed over the litharge-passage and charging-doors; these hoods connect with sheet-iron pipes which conduct the lead-fumes into the condensation-chambers. The fire and blast are now increased. The fuel used generally consists of wood, bituminous coal, and lignite; the two latter can only be employed when blast is conducted through pipes into the ash-pit; otherwise there would not be sufficient draught to support combustion. The remainder of the silver lead is charged as fast as the quantity in the furnace is decreased by the withdrawal of litharge. The pigs of lead are laid in the charging-door and allowed to fuse slowly. From ninety to ninety-six hours are necessary in cupelling 25,000 kilograms of silver-lead, and the consumption of fuel amounts to 40 scheffel of lignite, 5 scheffel of small bituminous coal, and 1.25 klafter of wood.

170. Products: *a.* A dross (=120 kilograms) called *abzug*, is that which first forms during the fusing, and is composed of the unmelted impurities of the lead. It is removed from the surface of the lead by means of a piece of wood fastened to an iron rod. Only a small quantity of abstrich is found.

b. Yellow litharge: It is tolerably pure oxide of lead, and contains from 0.04 to 0.06 per cent.=11 oz. 13 dwt. 4.8 gr. to 17 oz. 9 dwt. 19.2 gr. silver. It is delivered over to the Stolberg shaft-furnaces for reduction.

c. Red litharge: It contains less silver than the yellow variety, and is formed on the interior of large masses after cooling off. It is separated

from the yellow litharge by sifting, and sold, as it contains too small a quantity of silver to be reduced with profit.

d. Litharge containing bismuth: It is formed toward the close of the operation, as the bismuth oxidizes later than the lead. This litharge is reduced separately. The resulting silver-lead is also separately cupelled. Ores and products containing bismuth, also the residues from the operation of bismuth extraction, as well as a part of the cupellation-hearth, which is situated directly under the spot where the rich argentiferous lead collects toward the close of the process, are also reduced with the bismuth litharge. From 250 to 500 kilograms of bismuth litharge are produced in every cupellation.

e. "Scheide" litharge: This is that which collects and congeals on the sides of the litharge-canal. It is removed from time to time. From 250 to 400 kilograms of this variety are produced during a cupellation, and it is reduced in conjunction with the yellow litharge, as its chemical composition is the same.

171. *Manner in which the products are removed from the furnace.*—The litharge flows off from the surface of the molten lead through a small canal made in the side of the marl hearth, in the litharge-passage near the fire-bridge. This canal is made with a saw, and at first on the side of the litharge-passage nearest the fire-place. The litharge, after flowing through this canal, flows into a receptacle of sheet-iron and there forms pieces weighing from 750 to 800 kilograms. When this receptacle has become full, it is taken away from the furnace and the litharge dumped out. The canal must be constantly kept open by means of a hooked piece of iron, otherwise it would soon become stopped up with congealed litharge. If the iron receptacle for the litharge has been filled three times from the same canal, the canal is closed with a little moist marl, and lead is charged into the furnace through the charging-door, until the surface of the molten charge again reaches to the level of the breast-wall in the litharge-passage. The lead which is to be added to that already in the furnace, is placed upon the edge of the charging-door, where it gradually melts and flows down on the hearth. This second addition of lead allows of the cupellation of large quantities upon the same hearth, and is accompanied by a large saving of fuel, and other material. In this manner it is possible to cupel 20,000 kilograms of lead more, after the first 8,500 kilograms have been placed in the furnace. When the hearth has become full again, a new channel is made near the old one for the escape of the litharge; the receptacle for the litharge is filled three times from this channel and is then closed; more lead is added to the charge and a new channel made with the saw.

172. In this manner each channel can be used at least three separate times. When the receptacle for the litharge has been filled about twenty-seven times the process is finished. As the surface of the lead sinks lower and lower, the blast-nozzles, of course, must be so directed that the blast will strike the surface of the charge. Formerly the process

was continued until the brightening of the silver, but at present it is only driven until the lead contains about 60 per cent. silver, and a greater portion of the bismuth contained in the silver-lead. The cupelman must be able to distinguish when this period takes place by the height of the metallic bath in the furnace. The blast is turned off, the hood over the hearth swung back on its crane, and the plumbiferous silver is ladled out as completely as possible into iron molds. That remaining on the hearth is cooled off with water, and then pried out with crow-bars.

173. The reason for not cupelling the silver until it brightens is, that the bismuth, which is concentrated in the silver-lead alloy, can only be prevented from volatilizing when the oxide formed is immediately absorbed by the hearth. This, however, is not possible, as the hearth is already saturated with litharge; consequently the cupellation is interrupted at the point stated, and the further cupellation is conducted upon a new test and in a smaller furnace. Fuel is also saved in not brightening in the large cupellation-furnace, as toward the end a very strong fire would have to be kept up, and as the furnace is large and the amount of alloy on the hearth would be very small in comparison, there would be a great waste of heat. The resulting silver-lead alloy amounts to about 600 to 700 kilograms, which is further manipulated in the silver-refining furnace.

174. The hearth, which is saturated with litharge for 3 to 4 inches deep, is easily broken off and removed from the underlying marl, as it breaks off in conchoidal pieces and easily falls to powder. That part of the rest which is saturated with litharge is delivered over to the matte-smelting operation for further treatment, and the remainder is used over again in making a new hearth. That part, however, which was immediately under the silver-lead alloy toward the close of the operation, and containing bismuth, is reduced by itself.

175. *Silver-refining.*—This operation is simply the continuation of the foregoing, whereby the silver is forced from the oxidizable metals with which it is alloyed as it comes from the cupellation-furnace. The operation is continued until the silver possesses a fineness of $\frac{99}{100}$. The furnace employed for this operation is a small reverberatory furnace, similar to an English reverberatory furnace, only that it is of much smaller dimensions, has two small tuyeres, one on each side of the fire-bridge, and, instead of a stationary arch over the hearth, it has a movable hood. The hearth is composed of the same material as that of the cupellation-furnaces. It is stamped in on the bottom of the furnace. The bottom of the furnace is composed of pulverized fire-brick, tightly stamped. In the center of the hearth a small hollow is made for collecting the silver. As soon as the hearth has been stamped in, the hood is placed over the furnace and all crevices between it and the furnace are stuffed with loam. The hearth is now carefully heated by a fire built in the fire-place, which is gradually increased. This is necessary because there

are no canals in the foundation of the furnace for leading off the moisture. After three or four hours, when the hearth appears red-hot, the silver-lead alloy is charged into the furnace and the fire increased.

176. Manipulation.—When the silver-lead alloy has become melted, (in about an hour,) a slight pressure of blast is turned on in order to oxidize the lead and bismuth. A small channel is now made on the edge of the working-door in the side of the hearth for the escape of the litharge. A large amount of the lead and bismuth oxides formed are now absorbed into the test. After several hours, the amount of litharge formed begins to decrease, the litharge-channel is closed, and marl is strewn over the surface of the metal to absorb the oxides. This is removed from time to time and fresh quantities added until the close of the operation. In order to judge when the operation has been carried far enough, a tool is held over and close to the surface of the molten metal; if its image is distinctly reflected therein, the silver has reached the fineness wished. A sample taken out should also show but few yellow spots. Perhaps the best method of determining this point is to take a small sample in a ladle and allow it to cool off. If, on cooling, it should sprout, the process of refining is finished. The molten silver is granulated and then delivered over to the gold-separating works.

177. *Granulation of the silver.*—The melted silver is ladled out of the silver-refining furnace into a copper vessel filled with water, the vessel being swung around at the same time by a workman. The silver is hereby separated into granules, which are dissolvable in sulphuric acid of 66° Baumé. The water in the copper vessel must be often renewed, as it soon becomes warm. The granulated silver is dried in a drying-furnace.

178. The length of the refining operation depends upon the quality and quantity of silver-lead alloy treated, also the amount of fuel consumed in the operation. In order to refine from 500 to 700 kilograms of silver-lead alloy, as it comes from the cupellation-furnaces, ten to twelve hours are necessary, and 8 to 9 scheffel of bituminous coal are consumed. Two workmen are employed, a refiner and his assistant.

179. Products: *a.* Refined auriferous silver, containing 0.3 per cent.= 87 oz. 8 dwt. 14 gr. gold per ton, 99 per cent. silver, and traces of copper, lead, and bismuth.

b. Rich bismuth litharge. It is delivered over to the bismuth-extraction works.

Dross and test. They are both rich in bismuth, and are also delivered over to the bismuth-extraction works.

180. *The liquation of Pattinson dross.*—By this operation is to be understood the gradual melting-down of the dross in reverberatory furnaces, which is formed on the surface of the silver-lead in Pattinson kettles, so that the lead will settle down on the hearth of the furnace and the dross remain back unmelted.

Manipulation.—The dross is charged into the furnace with the charg-

ing-spade, and fine bituminous coal is added as a reducing agent. The lead is then melted out at a very low temperature, so that none of the dross may be fused. The lead, carrying with it the greater part of the silver, flows down and collects at the lowest point of the hearth. Another portion of dross is now charged into the furnace with small broken coal, after the liquated dross has been removed from the furnace. The operation is conducted in this manner until the hearth is filled with liquated lead. The lead is tapped off every twenty-four hours. From six to seven scheffel of hard slate-coal and four scheffel of small coal are consumed in twenty-four hours by this manipulation.

181. Product: *a.* Liquated lead, which is delivered over to the Pattinson works for desilverization.

b. Dross: It is delivered over to the operation of ore-smelting for the purpose of reduction.

182. *Reduction of litharge.*—This operation consists of a reducing smelting of the litharge in a Stolberg blast-furnace, whereby metallic lead and slag are the resulting products. The litharge is broken up into pieces about as large as a man's fist, and delivered at the charging-hole of the furnace, where it is fluxed with fluor-spar, lead-slag, and coke; the latter serves as a reducing agent and fuel at the same time.

183. A Stolberg furnace puts through in twenty-four hours from 3,500 to 4,000 kilograms of litharge, with 350 to 400 kilograms of fluor-spar and 3,500 to 4,000 kilograms of lead-slag, with a consumption of 2,500 kilograms of coke. To every ten trays of litharge ten trays of slag and four baskets (one basket equal about four volumes of a tray) of coke are charged into the furnace and equally distributed throughout the shaft. The reduction of the litharge takes place very rapidly, and the lead must be tapped off very often. Seven men are employed at the furnace, namely, one smelter, two chargers, one slag-runner, two lead-ladlers, and one assistant. The operation is conducted with a dark charging-hole and a strong pressure of blast.

184. Products: *a.* Lead, which is delivered over to the Pattinson works for desilverization, without being previously refined.

b. Slag, containing up to 15 per cent. lead. It is principally used as a flux in the ore-smelting and various matte-smelting operations when the furnaces are smelting too rapidly.

185. MANIPULATION OF SPEISS.—The object of this operation is the partial desilverization of the speiss and the concentration of the nickel and cobalt. Speiss from the lead-matte and matte-concentration operations, and that produced by the preparatory manipulation of the blendic ores for the lead-smelting, are treated by this operation. The speiss generally adheres to the bottom of copper and lead matte, and must be separated from it, after which it is crushed and then roasted. After the roasting the speiss is principally composed of sulphates of the metallic oxides and uncombined oxides. The roasted speiss is smelted with baryte, copper-slags, copper-ores, lead-slags, litharge, and lead-

scraps poor in silver. The iron is slagged off, and the other metallic oxides and metals form a rich matte, while the cobalt and nickel form a speiss; silver-lead is also produced, which contains most of the silver in the charge. The amount daily smelted is composed as follows:

	Kilograms.
Roasted speiss	5,000
Baryte	750
Lead-slag	100
Quartz	300
Litharge	5,000
Total	11,150

From five to six smeltings are necessary to desilverize the speiss.

186. Products: *a.* Speiss, with 0.25 per cent.=7 oz. 5 dwt. 18.24 gr. silver, 17 per cent. copper, 2 per cent. cobalt, 20 per cent. nickel, and 4 per cent. lead. It is sold at Aberschlema. Copper-matte, which goes to the matte-smelting operations.

b. Silver-lead, which is delivered over to the refining-works. Poor slag, which goes to the slag-dump.

187. *Smelting of the roasted matte.*—The smelting of the roasted matte generally takes place at the end of a lead-ore-smelting campaign, or when large quantities of lead-matte have accumulated. This operation has for its object the diminishment of the lead and silver contents of the matte and the concentration of its copper. The matte to be treated is crushed and then thoroughly roasted in long reverberatory roasting-furnaces, or broken up into pieces of about the size of a walnut and roasted in kilns or roasting-stalls. In preparing the smelting-charge no definite proportion is adhered to between the ore and the products to be smelted. As clean slags are produced in this operation, they are employed in smelting over slags that receive a second treatment; such slags are produced in smelting the roasted lead-ores, and the roasted lead-matte takes the place of the pyritous ores, which are charged into the blast-furnaces for the purpose of forming a matte in the slag-smelting. The roasted lead-matte is smelted with an equal amount of raw lead-matte and an addition of plumbiferous products, sweepings, and residues from the zinc and arsenic works. Such a smelting-charge is composed of—

	Cwt.
Raw lead-matte	90
Refining dross	60
Zinc residues	8
Iron residues	8
Rich lead-slag	40

Such a charge, of course, smelts very rapidly, as it is composed of products which have already passed through smelting operations.

187. The following are the products of this manipulation:

a. Slag, which goes to the slag dump, as it only contains from 0.0015 to 0.002 per cent.=8 dwt. 16.66 gr. to 11 dwt. 15.84 gr. silver, and 1 to 2 per cent. lead.

b. Lead-matte, which is crushed and roasted in furnaces or broken up into pieces and roasted in kilns, or stalls, and resmelted for the purpose of the further concentration of the copper, after which it is called copper-matte.

c. Silver-lead, which, after undergoing a process of refining, is delivered over to the Pattinson works for desilverization.

189. The manipulations in this operation are the same as those described under the head of "lead-ore smelting." This operation is very effective in cleaning the furnaces of all accretions which may have been formed during previous operations, and thus makes the work of cleaning out the furnaces much easier. Especially all accretions which may have formed in the bottom of the furnaces are effectually removed. For this reason, the operation is always carried out at the end of the lead-ore-smelting campaign, or when a furnace has become partially stopped up.

190. RESMELTING OF THE LEAD SLAGS IN BLAST-FURNACES.—The so called Freiberg slag-smelting is in reality a combined slag and matte smelting. The object of this operation is the concentration of the small amounts of silver, lead, and copper contained in various metallurgical products in a matte resulting from the smelting of poor argentiferous pyritous ores, after a previous roasting. The operation is conducted in blast-furnaces; formerly, however, only in reverberatory furnaces. Instead of the roasted pyritous ores, roasted lead-matte is now principally made use of in fluxing. The operation is generally conducted in the Pilz furnaces. A double purpose is effected by the operation of slag-smelting, namely, the extraction of lead and silver from the slag and the concentration of the matte.

191. The composition of the smelting charge is naturally changeable. It is customary to resmelt the lead-matte resulting from the ore-smelting (containing about 15 per cent. copper) as often with the operation of slag-smelting as is necessary to increase its amount of copper to within 23 per cent.

The following is the composition of a slag-smelting charge:

Muldener Works.

	Kilograms.
Slag from ore-smelting	100. 0
Copper-slag	4. 0
Raw copper-matte	2. 3
Lead-matte roasted in kilns	4. 3
Lead-matte roasted in kilns and a second time in stalls	8. 4
Lump pyrites, roasted in kilns	9. 0
Speiss from the dezinckification process	1. 0
Dezincking residues	1. 0

	Kilograms.
Limestone	2.0
Fluor-spar	2.0
Refining dross, test, abstrich, &c	7.2

Halsbrückner Works.

Slag from ore-smelting	100.0
Copper-slag	15.0
Raw copper-matte	1.8
Roasted lead-matte	21.0
"Stockeln"	4.0
Argentiferous copper	1.1
Refining dross, &c	5.8

As will be seen from the above, several products carrying a large percentage of sulphur help to compose the charge; for instance, raw-matte and lead-matte. The reason of this is the same as by the ore-smelting—it is for the purpose of dissolving the zinc.

192. The manipulation of the furnaces with eight tuyeres is the same as described by the smelting of ore. The pressure of blast is also the same. About 50,000 kilograms are smelted per day. One kilogram coke smelts 10 kilograms of charge, less, therefore, than by the ore-smelting. The slag produced is quite basic. The author is unable to give complete analyses, but the following will show the principal ingredients. They are taken from the work of Kast & Bräuning:

Slag from Muldener Works.		Slag from Halsbrückener Works.	
SiO_2	29.7	SiO_2	34.01
ZnO	8.5	ZnO	7.6
PbO	2.5	PbO	1.0
Ag	0.0025	Ag	0.0015

193. The products of this manipulation are:

a. Slag, which goes to the dump, as it only contains 0.0025 to 0.002 per cent.=8 dwt. 17.66 gr. to 11 dwt. 15.84 gr. silver, and from 1 to 2 per cent. lead. Copper-lead-matte, with 17 to 25 per cent. copper, which is again smelted.

b. Silver-lead, containing from 0.6 per cent. to 0.7 per cent. = 174 oz. 19 dwt. to 204 oz., 2 dwt. silver, which, after being liquated and refined, goes to the Pattinson process.

194. *Second smelting of matte.*—The object of this operation is the resmelting of the lead-matte which has been roasted in kilns or stalls. Silver-ores rich in copper are also often treated in this operation, after undergoing a previous roasting, when deemed necessary. The results aimed at by this manipulation are the concentration of the lead sulphide, iron protosulphide, &c., contained in the roasted matte and ores, with the copper sulphide, into a product called copper-matte, and at the same time to reduce the lead and silver and slag off the iron to within a cer-

tain degree. The roasted lead-matte is smelted with rich slag from the ore-smelting and with slag from the operations of litharge and lead-dross reduction. This produces a thick flowing slag. Cupellation test and copper scraps are also generally added to the charge. This operation effects the further concentration of the copper in the remaining concentrated matte, and a partial extraction of its lead and silver, of which it contains but a small quantity. Special care must be taken in roasting the copper-matte, as it fuses much more easily even than the lead-matte. It should be mentioned here that the copper-matte is repeatedly added to the matte-slag-smelting until the matte contains about 23 per cent. copper.

195. The following will serve to show the composition of a charge for the second matte-smelting:

	Kilograms.
Unroasted copper lead-matte	100
Roasted pyritous silver-ores	400
Copper slimes, made into balls with solution containing copper-vitriol	400
Slag from copper-matte concentration	400
Slag from ore-smelting	3,333

196. The production, besides silver-lead, which is liquated, refined, and then desilverized by the Pattinson process, are, concentrated matte, containing 0.15 per cent. = 43 oz. 13 dwt. 14.40 grs. silver, 13 per cent. lead, and 30 to 42 per cent. copper. The slag is so poor that it undergoes no further treatment. Speiss is very often produced; also, plumbiferous black copper, carrying arsenic, lead, and antimony. The black copper is either smelted over with the slag-litharge reduction, raw copper-matte, raw copper-ore, and silver-lead, or is added to the matte-smelting charge.

197. The following will serve to show the changes which the matte undergoes during its three operations of concentration:

1st. The matte contains 0.25 per cent. = 72 oz. 17 dwt. 14.4 grs. silver, 15 per cent. lead, and 6 to 12 per cent. copper.

2d. The matte contains 0.23 per cent. = 69 oz. 0 dwt. 19.2 grs. silver, 21 per cent. lead, and 20 to 25 per cent. copper.

3d. The matte contains 0.17 per cent. = 49 oz. 10 dwt. 4.8 gr. silver, 15 per cent. lead, and 33 to 44 per cent. copper.

An analysis of the 3d, or concentrated, copper-matte, made in Clausthal, of matte from the operation of May, 1870, shows the following composition:

	Per cent.
Copper	32.9
Silver	0.25
Lead	15.0
Iron	19.5
Sulphur	23.8

198. *Roasting of the concentrated copper-matte.*—The copper-matte, containing on an average 40 per cent. of metallic copper, is finely crushed, and so roasted in long reverberatory furnaces that it only contains about 5 per cent. of sulphur. This is accurately observed, for the roasting must not be conducted too far, otherwise there would be a lack of sulphur in concentrating the matte in reverberatory furnaces, to form with the copper a disulphide; and also, on the other hand, it must be carried far enough, in order that the protosulphide of iron be converted into sesquioxide of iron as completely as possible, so that it may be slagged off. For the last-mentioned reason, the roasting is carried a little too far, thus not leaving sufficient sulphur to form a disulphide with all the copper, but during the following concentration, substances containing sulphur are added in sufficient quantities to make up the deficiency. The material used for this purpose is raw-copper-matte.

199. As the concentrated matte fuses very easily, on account of its high percentage of copper, it cannot well be roasted in kilns or shaft-furnaces, and, consequently, cannot be employed for the manufacture of sulphuric acid. Formerly it was roasted in muffle-furnaces; but at present a small reverberatory furnace with double hearth is employed for this purpose. Any small reverberatory furnace could, however, be made to fulfill the same purpose.

The furnace is continually charged every three hours with 10 to 14 cwt. of concentrated matte, and about 80 to 110 cwt. can be roasted daily. The temperature is always kept at a lower degree than in the roasting of ores or other metallurgical products. The consumption of fuel per 1 cwt. of copper-matte amounts to 30 or 36 cwt. of bituminous coal, of poor quality, which contains from 20 to 25 per cent. ash.

The cost of roasting 100 cwt. of matte in 1869 was as follows:

	*Thaler.	Sgr.	Pf.
Wages, including transportation	5	25	10
Fuel	4	16	5
Repair of furnace and tools	4	19	1
Total	15	1	4

The cost of crushing 100 cwt. of the matte amounted to 37 thaler.

200. After the matte has been roasted, its principal ingredients are oxide of copper, basic sulphate of copper, basic sulphate of the sesquioxide of iron, metallic silver, sulphate of silver, sulphate of lead, oxide of zinc, oxide of nickel, oxide of cobalt, and some arseniates and antimoniates.

201. *Concentration of the concentrated matte in reverberatory furnaces.*—The construction of the reverberatory furnace is as follows: The foundation of the furnace is either composed of bricks or broken gneiss; the surrounding walls, however, of bricks. It has two principal parts, namely, the fire-box and the smelting hearth. The former consists of a

* A *thaler* = 30 *silbergroschen;* one *silbergroschen* = 12 *pfennige.* A *thaler* = 71 cents gold.

wind-furnace and an ash-pit, separated from each other by the grate. The smelting-hearth is separated from the fire-place by the fire-bridge; opposite the fire-bridge, and in the arch over the hearth, is situated the flue opening, connecting with a chimney by means of an inclined flue. Iron plates form the lowest part of the hearth, these resting upon pillars below the floor of the furnace-house. These pillars are generally built of well-burnt brick. On top of the iron plates there is a layer of bricks, and on this comes the smelting-hearth, which is composed of five parts of finely-crushed quartz and one part of slag. The hearth is oval and concave, and has a slight incline toward the tap-hole. It is spanned by an arch, which at the same time covers the fire-place. In the center of this arch is a charging-hole. The fire-bridge is composed of a mixture of unburnt fire-clay and dust of fire-bricks, (chamotte,) and rests upon an iron plate. Passing through it is an air-canal, which serves to keep it cool. On either of the longer sides of the furnace are two openings, (generally kept bricked up,) through which a man can pass into the furnace, in order to make repairs when necessary. The fire-place is furnished with a charging-door; opposite the fire-bridge is a working-door under the flue, which can be opened and closed by means of a fire-clay slab attached to a lever. In front of the working-door there is a horizontal bar, upon which the heavy furnace implements can rest when not in use. The tap-hole is on the side opposite to the fire-place door. All parts of the furnace which come in contact with the flames are constructed of fire-clay bricks. The furnace and chimney are well anchored. Behind the anchor-rods are cast-iron plates. The flue connects with a flue-shaft, the gases passing through this flue into condensation-chambers or directly into the chimney. This grate is 4 feet square, and has thirteen wrought-iron bars 4 feet long and 2 inches square. The ash-pit is 5 feet 6 inches high. The fire-door is 16 inches wide on the outside and 4 inches on the inside; on the outside 18 inches high and 14 inches on the inside. It is lined with thin iron plates. The fire-bridge is 4 feet long, 2 feet 6 inches wide, and 12 inches high above the hearth; above the grate, 3 feet 2 inches high. The length of the hearth, from the fire-bridge up to the wall of the working-door opposite to it, is 13 feet; the greatest width is 8 feet; at the fire-bridge it is 4 feet wide, and under the flue-opening only 1 foot 2 inches. Its greatest depth near the tap-hole is 16 inches. The flue-opening in the arch over the hearth has the shape of a trapezium, and is 12 inches wide, 2 feet 8 inches long at the back, and 2 feet 4 inches in front. The height of the flue at this point is 1 foot 6 inches, measured at right angles to its incline. The section of the flue-canal where it opens into the chimney measures 22 inches in width and 2 feet 6 inches high. The chimney is 60 feet high, and consists of an outside wall and lining, and is 2 feet 4 inches wide, inside measurement. The stone supporting pillars, generally ten in number, are in horizontal section 12 inches square, and are 2 feet 6 inches high. The iron plates composing the lower part of the hearth are 2 inches

thick, 2 feet wide, and vary in length according to the shape of the hearth. The air-slit in the fire-bridge is 3 inches wide and 16 inches high. The tap-hole has a diameter of 8 inches in the interior of the furnace, and on the exterior of 3 inches. The arch over the hearth is 12 inches thick; the charging-hole in the arch measures 12 inches square. The layer of bricks resting on the hearth-plates is 6 inches thick, and the layer above, of melted quartz and slag, is 12 inches thick.

202. *Melting on the hearth.*—The proper conduction of this operation is as important as it is difficult. The material used is a mixture of five parts of finely-crushed, burnt, and sieved quartz and one part of raw slag, which has been treated similarly to the quartz. After these materials have been carefully mixed, about 50 cwt.* of the mixture is charged upon the hearth of the furnace and evenly spread out. It is then brought to a red-heat and well raked until all moisture has been removed. Then begins the forming of the hearth with the "forming-ladle;" this accomplished, the furnace is closed on all sides, and all crevices between the doors and walls are luted with fire-clay; the furnace is then fired up as strongly as possible. After twelve hours of continual firing, during which time the hearth-material has become pasty, and appears glazed on the surface, the furnace is opened and the hearth examined, in order to discover if any cracks have formed in the layer. If such is the case, the hearth-material must be drawn out of the furnace and the operation performed over again. Twenty more hundred-weight of slag are now melted on the hearth, in order to give it greater durability, and after it has been drawn out through the working-doors into the sand-beds, the actual operation of matte-concentration begins. A hearth prepared in this manner will generally last from one and a quarter to one and a half years. The life of the arch over the hearth is about one and a half to two years. The slag-beds in front of the working-doors are composed of a layer of moistened sand and coal-ashes. In front of the tap-hole and along the entire length of the furnace are a number of cast-iron pans having the shapes of truncated pyramids. The matte is tapped off into these pans, which connect with each other by troughs.

203. We will now proceed with the matte-concentration in reverberatory furnaces. This operation has for its object the production of a bisulphide of copper, containing at least 70 per cent. of metallic copper, and, at the same time, to separate the oxide of iron and the other metallic oxides, by slagging them off. The iron, especially, must be separated from the matte to within at least 0.2 per cent., if the following operation of the production of copper-vitriol is to be conducted to advantage. The roasted concentrated copper-matte is smelted in reverberatory furnaces with baryte, quartzose, and dry silver-ores, (*dürrerze*,) carrying as much baryte as gangue. The roasted matte is principally composed of metallic oxides, and contains such a small amount of sulphur that it is not

* 1 centner, or cwt. = 110 pounds English.

sufficient to convert all the copper into a disulphide. The lack of this element is supplied by baryte, (Ba O, SO_3.) This is reduced to sulphide of barium, which, in contact with oxide of copper, is converted into sulphide of copper and oxide of barium. The sulphide of copper produces the concentrated copper-matte; and the oxide of barium, it being a strong base, combines with the silicic acid and is thus carried off by the slag. A reaction can also take place in a different manner; the baryte, on being smelted, together with silicic acid, would part with its sulphuric acid, which, on coming in contact with oxide of copper, would be reduced and form a disulphide with that metal. The silver is dissolved in the matte as sulphide of silver.

204. The operation can never be so accurately conducted so that slag and concentrated matte only will result; some black copper, containing lead and matte, poor in copper and rich in iron and sulphur, is almost always produced. The production of black copper could be avoided if the roasting of the concentrated matte were not conducted so far, but if this were done, too much protosulphide of iron would remain in the matte. The fluxes used in the smelting are quartz, or siliceous, dry silver-ores and baryte, the latter also supplying any lack of sulphur in the charge. If metallic copper forms, several hundred-weights of roasted concentrated matte are added to the charge. The general make-up of the charge is as follows:

	Per charge per 100 cwt. of concentrated matte.		
Roasted concentrated matte....		22 cwt.	
Raw copper-matte from the same operation	3 to 6	22 cwt.	14 to 27 cwt.
Black copper-matte from the same operation		5 cwt.	23 cwt.
Baryte	6 to 7	5 cwt.	25 to 30 cwt.
Unroasted siliceous, dry silver-ores........................	3 to 5	5 cwt.	14 to 23 cwt.

Sometimes, during the first part of the smelting operation, fluorite instead of baryte is added in order to make a more fusible slag. All material composing the charge, with the exception of the black copper, is finely crushed. Bituminous coal, of the best quality possible, is employedas fuel.

205. Manipulation.—The manipulations are as follows: As soon as the charge has been put into the furnace, it is spread out over the hearth, a greater amount being placed near the fire-bridge than elsewhere. This serves to protect the fire-bridge from the great heat, and a part of the charge melts much quicker. After this has been executed, a layer of loam is placed before the working-door and tightly pressed down with the shovel upon the lower side of the door. This serves as a dam to the molten slag, which would otherwise flow over the door, especially if the furnace contained several charges. The working-door is now closed by lowerin g

the fire-clay slab, before mentioned, and all crevices are stuffed with moistened sand. The grate is well cleaned out and the fire-places filled with fuel up to the top of the fire-bridge, in order to produce as high a temperature in the furnace as possible. The grate is cleaned every half hour by poking from below in the ash-pit. It is cleaned from clinkers by passing an iron rod through the fire-door, but in such a manner that as little heat as possible may be lost. From two and a half to three hours after the charge has been spread over the hearth, it is in a molten state, when the furnace works well, and the charge must then be worked through with an iron rabble, in order to avoid the formation of accretions on the bottom of the hearth. The doors are now again closed and the fire urged to its utmost. The condition of the hearth is the only means which the smelter has to judge of the progress of the smelting, and this he must inform himself of when working through the charge with the rabble. For instance, if in passing the rabble over the surface of the hearth it feels as if it were sliding over a sandy surface, the hearth is in proper condition and the charge is completely melted. On the other hand, if the hearth should feel greasy or smooth, the heat must be increased. From one-half to three-fourths of an hour after the charge has been rabbled, the slag is drawn out over the working-door by means of a short slag-hoe, and runs on the slag-bed, on the floor of the smelting-house. The slag is allowed to cool, and is then drawn out with hooks, placed upon a slag-car and transported to the slag-heap. The slag-bed has been destroyed, by the slag flowing on to it, and therefore has to be made over again. After the slag has been withdrawn from the furnace a new charge is allowed to fall upon the hearth, a new slag-dam is made upon the working-door, and the smelting is conducted in the same manner as before. After the second charge has become smelted and the slag removed, a third charge is added, and when the hearth has become filled with matte, the furnace is tapped and the matte flows out into the iron basins under the tap-hole. A charge weighs from 33 to 36 cwt. In twenty-four hours from four to six charges are smelted, and two to three tappings generally take place. The matte on becoming cool is pried out of the basins, placed on small carts and carried away. The matte is not granulated when tapped off, as the granules would not be small enough for its further manipulation. Before the matte is delivered over to the copper-vitriol works, its percentage of iron is determined, and if it amounts to more than 0.2 per cent. it must pass once more through the operation of concentration. After every tapping the interior of the furnace is patched with a moistened mixture of two parts of finely crushed quartz and one part of fire-clay. This is made up into balls, placed upon the under side of a long ladle and stamped by means of the same about the fire-bridge and round the sides of the hearth. In order to be able to see the parts which need repairing most, a new charge is allowed to fall upon the hearth, and as this lowers the temperature considerably, the light is not quite so blinding.

206. Three men work at each furnace, viz, one smelter and two assistants; they make twelve-hour shifts. The smelter is paid 18 to 25 silbergroschen, and the two assistants receive 15 to 17 silbergroschen per shift. The consumption of fuel per twenty-four hours amounts to 7,600 pounds = 3,800 kilograms of common coal, and a like amount of coal of a poorer quality.

207. The products of this operation are:

a. Plumbiferous black copper, assaying from 0.50 to 0.60 per cent. = 145 oz. 16 dwt. to 174 oz. 19 dwt. 16 gr. silver, 20 to 25 per cent. lead, and from 50 to 60 per cent. copper. Part of it goes to the ore-smelting, and another part goes through the same concentration operation again.

b. Concentrated copper-matte, assaying from 0.29 to 0.40 per cent. = 84 oz. 10 dwt. 19.2 gr. to 116 oz. 12 dwt. silver, 3 to 7 per cent. lead, and 70 to 73 per cent. copper. It also contains at the highest 0.3 per cent. iron, otherwise the matte would not be fit for treatment with sulphuric acid, as the copper-vitriol produced must be free from this impurity.

c. Slag, carrying 0.005 per cent. = 1 oz. 9 dwt. 3.84 gr. silver, 9 per cent. lead, and 6 per cent. copper. When it is richer in metals than here given it passes through the same operation again, but it generally goes to the ore-smelting, where it gives a flux of the desired quality. It is quite fusible, blackish-brown in color, and has a high specific gravity, in consequence of its high percentage of baryte; but notwithstanding this fact it separates well from the matte.

208. *Manufacture of copper-vitriol.*—The copper-vitriol is manufactured at the Halsbrücken Works, and for this purpose the concentrated roasted copper-matte is sent there from the Muldener Works. The principal product of the copper-matte concentration in reverberatory furnaces is the concentrated copper-matte, and it is from this product that the copper-vitriol is manufactured. Its principal ingredient is disulphide of copper, but it is also generally impregnated with metallic copper, which, by stamping, is flattened and separated from the matte by the following operation of sieving.

The chemical composition of the concentrated matte is at the present time about as follows:

	Per cent.
Copper	69.00 to 74.00
Lead	3.00 to 7.00
Silver	0.30 to 0.40
Iron	0.20 to ——
Cobalt and nickel	0.30 to ——
Arsenic and antimony	0.50 to 1.00
Sulphur	14.00 to 19.00

209. Before the concentrated matte is treated with sulphuric acid, it undergoes an operation of crushing and roasting, in order to convert the disulphide of copper and sulphide of silver into oxide of copper and

metallic silver. It is crushed under stamps and then thrown on to a sieve, which has five meshes per square centimeter. The roasting is conducted in Freiberg muffle roasting-furnaces with double hearth. The muffle, however, is not made use of, the matte being charged only on the hearth.

An arrangement has lately been adopted by which the entrance of the hot gases from the lower hearth into the upper may be regulated by means of a damper, but are, under the present circumstances, conducted directly away. The concentrated matte agglomerates very easily, and must at first be roasted with the greatest care, at a very low temperature, and accompanied by continual workings of the charge. The temperature must not be raised until a greater part of the sulphur has escaped.

In consequence of the above reasons, only one charge can be roasted at a time. An average charge is about 500 kilograms, and it should not lie on the hearth more than 5 centimeters thick.

The roasting lasts sixteen hours. During the first six hours the furnace is kept quite dark; during the next four hours a moderate temperature is employed; and in the following three hours it is gradually increased to a white heat, the charge remaining under its influence for three hours longer, and constantly stirred.

If the stirring of the charge should be discontinued, protoxide of copper would be formed in large quantities, which, on being treated with dilute sulphuric acid, would be decomposed and converted into peroxide and metallic copper, and this would cause the extraction-residues to contain large amounts of copper.

The roasted matte should therefore appear bluish-black from peroxide, and not red, as this latter color shows the presence of the protoxide of copper. It always contains from 0.5 to 1.5 per cent. sulphur, and on an average 1 per cent., in consequence of the formation of small agglomerated lumps during the first part of the roasting operation. This cannot be well avoided. The lead contained in the matte also helps to retain a portion of the sulphur, as the sulphate of lead formed is not decomposed in the highest of temperatures.

210. Two workmen are necessary to each furnace; they make ten-hour shifts, and are paid from 15 to 18 silbergroschen. Only from 13 to 14 hundredweight of matte can be roasted in twenty-four hours in one furnace. The consumption of fuel per 5,000 kilograms of charge amounts to from 5,500 to 6,000 kilograms of bituminous coal of the best quality possible.

211. After having passed through the operation of roasting, the charge is sifted; the remaining lumps, consisting of agglomerated sulphide of copper and lead, are again crushed and roasted; that which passes through the sieve, however, is ground still finer, until it is almost of the consistency of powder. It principally consists of the following substances: peroxide of copper, small amounts of sulphate of peroxide

of copper, protoxide of copper, metallic silver, also gold and sulphate of lead; besides these, it contains small amounts of oxide of iron, oxide of cobalt, oxide of nickel, basic arseniate, and antimoniate salts, among which there is perhaps a small amount of arseniate of silver.

212. *Treatment of the roasted copper-matte with sulphuric acid.*—If the roasted matte be treated with dilute sulphuric acid for some time, and boiled, the peroxide of copper and the other metallic oxides will dissolve, while metallic silver gold, and sulphate of lead remain undissolved. The presence of protoxide of copper causes the precipitation of the metallic copper, and although it precipitates any metallic silver which may have been dissolved, still it is not desirable that it should be present in large quantities, as it remains undissolved. Peroxide of iron, oxide of nickel, and oxide of cobalt are only dissolved in small quantities, and very slowly, while the solution is cold, but when the solution is boiled, they are completely dissolved, and enter into the vitriol solution. In the presence of metallic copper and the protoxide, the oxides are converted into protoxide salts. The arseniate and antimoniate salts, especially the basic arseniate and antimoniate of silver, are only slowly decomposed in cold dilute sulphuric acid, but on heating they are rapidly decomposed, whereby sulphate salts and uncombined arsenic acid and hydrated antimonic acid are formed, the latter of which partially remains undissolved, while all the other substances remain in solution. The silver dissolved in this manner is, however, immediately precipitated when metallic copper or its peroxide is present.

213. It will be perceived from the foregoing, that there remains an undissolved residue, when the roasted concentrated copper-matte is treated with dilute sulphuric acid, which consists of metallic silver, gold, copper, sulphate of lead, and hydrated antimonic acid; the solution, on the other hand, contains the sulphate salts of peroxide of copper, nickel, cobalt, and iron peroxide; also a small amount of arsenic acid and antimonic acid. Copper-vitriol is produced from the solution by crystallization, whereby the other sulphate salts remain in the mother-liquid.

214. The fine powdered state which the matte is in, and necessary to the operation of dissolving, offers difficulty to the practical working of the process, as thick crusts are easily formed, which are impregnated with sulphate of copper. At present this disadvantage is overcome by passing steam through the solution during the process of dissolving. High cylindrical vessels of solid antimonial lead have been employed for several years in dissolving the matte. They have a capacity of 1.24 cubic meters; just above the bottom there is a short pipe, used for letting off the silver slimes. There are eight of these dissolving-vessels; four of them are employed for dissolving the roasted matte and the other four for the redissolving of the raw vitriol. They weigh from 1,250 to 1,500 kilograms, and cost from 200 to 240 thaler; they last, however, for a very long time. Above the dissolving-vessels there are reservoirs for sulphuric acid, water, and raw solution; the liquids are forced up

into these reservoirs by means of compressed air. The dissolving-vessels are filled 0.36 meter high with raw chamber-acid of 49° to 50° B.; it is then brought to the boiling-point by passing superheated steam through it for one and one-half hours, it being at the same time thereby diluted. The steam is heated by means of a system of bent pipes, which pass over a fire-place. Three hundred weight of roasted matte are then gradually charged into the vessels, and the liquid continually stirred. Steam is still passed through, in order to raise the acid up to its boiling-point. The steam-pipe passes in at the top and down to within 0.07 meter of the bottom, so that the residues may be continually kept in motion by means of the steam. The length of this period is about one and one-half hours; mother-liquid is then added until the vessel is about full, and the whole solution is again raised to its boiling-point by steam.

215. The solution, now diluted to 32° B., is allowed to stand for two hours, and is then drawn off into a settling-tank by means of a siphon. After remaining in the settling-tank for an hour, it is drawn off into a crystallizing-tank. The whole operation of dissolving lasts five hours; 1,650 kilograms of matte are dissolved in four vessels within twenty-four hours. It takes nine days to crystallize the vitriol. The first fourth of the copper-vitriol crystals are ready for market as raw vitriol, the other three-fourths are dissolved again in hot water and re-crystallized. The crystals are dissolved in a half-cylindrical-shaped vessel of lead, perforated on all sides; this is hung within another vessel, of antimonial lead, by means of three hooks. The larger vessel is filled with water. The lead-sieve is made half cylindrical, in order that the steam-pipe can pass into the water. The good vitriol solution is filtered through copper granules before being discharged into the crystallizing-tank, in order to separate any silver or slimes that may have been contained therein. The copper used for this purpose is argentiferous, finely granulated. The copper-granules are placed in a half-cylindrical-shaped vessel of antimonial-lead, which has a double bottom, the upper one being perforated, and covered with linen, to avoid the falling through of the granules. This manipulation of filtering also serves to make the solution almost neutral, whereby beautiful large crystals can be obtained from it.

Sheet-copper is also hung in the crystallizing tank for the purpose of keeping the solution neutral during the operation of crystallization. When a deposit of metallic copper forms on the sheet-lead lining of the tank, or even on the crystals, it is an indication that the solution is about neutral. A deposit of slimes on the bottom of the tank is not considered of disadvantage, though small crystals of vitriol form there, but they are again dissolved with the raw solution. It takes nine days to crystallize the purified solution. When the operation is finished, the crystals are broken from the lead-strips and washed with cold water in order to give them a better appearance and to remove the pulverized vitriol, made by knocking the crystals from off the lead-strips. The crystals

are dried upon wooden tables in a special drying-chamber and are then ready for market.

216. The annual production of copper-vitriol amounts to about 1,050,000 kilograms. (1,050 tons of 1,000 kilograms.) It is manufactured from 400,000 kilograms of concentrated copper-matte with the employment of eight dissolving-vessels and one hundred and four crystallizing-tanks. To this amount should be added about 50,000 kilograms more of copper-vitriol produced in the gold-separating establishment.

217. The mother-liquid is used again for dissolving the raw crystals; it is then concentrated and crystallized. The crystals hereby produced contain 0.035 per cent. iron, and are again dissolved, and then go through a second operation of crystallization with the main solution; the mother-liquid, which is rich in iron and contains 1 kilogram of copper to the 0.024 cubic meter, is removed and is used in making roasting-balls out of ore-slimes. The argentiferous residues remaining on the bottom of the dissolving-vessels after the treatment of the matte with sulphuric acid, are removed into large pointed boxes lined with sheet-lead; there they are boiled with steam; sulphuric acid is added when deemed necessary, and they are then allowed to settle. There are two of these pointed boxes, each connecting with a trough on the side by means of rubber-hose, which are furnished with Mohr's spring-clamps. The trough has twelve openings in the bottom, under each of which there is a small pointed box. These latter are perforated on all sides, and on the inside have a filter of ticking, which is fastened above to a lead frame. After the wash-water in the large pointed boxes has become clear, it is gradually allowed to flow out through the three pipes in the side, and is used in the next following operation of dissolving. The argentiferous slime is allowed to flow off into the trough and from here it flows on to the filters in the small pointed boxes. It is scraped from the filters and dried upon an iron hearth. It amounts to about 17 per cent. of the original amount of matte. In 1869 it contained on an average, besides other ingredients, the following: 1.94 per cent. = 565 oz. 1 dwt. 4.8 gr. silver, 41 per cent. lead, and 11 per cent. copper. Lately, however, the copper contents have decreased to 5 per cent.

Since the solution from crystallization has been filtered through copper granules, stronger acid can be used for dissolving, without fear of making the vitriol rich in silver; and the amount of copper contained in the argentiferous slimes is also decreased.

The argentiferous slimes, after having been dried, are delivered over to the operation of ore-smelting for further treatment, where it is added in small quantities to the ore-charge.

The workmen are paid according to the amount produced, and receive 5.7 silbergroschen per 50 kilograms of raw vitriol, and 1½ silbergroschen per 50 kilograms of purified vitrol produced.

218. The results of the manufacture of copper-vitriol at the Halsbrückner Works, in 1869, may be seen from the following figures:

	Total.	Per cwt. of matte.
Concentrated copper-matte dissolved..	7,943 cwt. 30 lbs.	100 cwt.
Other material dissolved.............	21 cwt. 38 lbs.	
Sheet-copper for neutralizing dissolved.	17 cwt. 84 lbs.	0.22

Results.

	Total.	Per cwt. of matte.
Copper-vitriol, impure, (exclusive of 970 cwt. from the operation of gold separation)................................	19,881 cwt. 11 lbs.	251.38 cwt.
Copper vitriol, purified................	140 cwt. 15 lbs.	
Extraction residues, (argent. slimes)....	1,306 cwt. 96 lbs.	16.41 cwt.
Solution, (as increase to the intermediate products with 3 lbs. copper per cub. ft.)	3,009 cwt. 50 lbs., (or 5,420 cub. ft.)	68 cub. ft.
Mother-liquid with 2 lbs. copper per cub. ft., (used for making roasting-balls)	7,862 cwt. 25 lbs., (or 14,295 cub. ft.)	180 cub. ft.

Material consumed.

Raw chamber acid.....................	15,668 cwt. 97 lbs.	
Or, reduced to 66° sulphuric acid	10,028 cwt. 12 lbs.	196.7 cwt.

	Cwt.	Cwt.
Bituminous coal for roasting matte	9,286	125.9
Bituminous coal for heating the steam-boiler	9,912	116.6
Bituminous coal for evaporating the solution	8,058	
Bituminous coal for drying the copper-vitriol	1,566	
Bituminous coal for drying the argentiferous residues ..	505	
Total	2,041	251.15

Production.

Number of working-days at the roasting-furnace	632
Number of working-days at the operation of dissolving, &c	300

In twenty-four hours were—

	Cwt.
Concentrated matte, roasted	12.6
Concentrated matte, dissolved, &c............................	26.6
Copper-vitriol produced	70.0

219. *Estimate of the amount of metal extracted from matte in* 1869.

A.—*Treated.*

In 3,321 cwt. 70 lbs. copper-matte from the Muldener Works, as—

Cwt.	lbs.		P. c. Ag.	P. c. Pb.	P. c. Cu.	Gold. Lbs.	Silver. Lbs.	Lead. Cwt. lbs.	Copper. Cwt. lbs.
1,110		à	0.32	3	74				
880	90	à	0.34	2	74				
676	90	à	0.41	6	69		1,203.45	121 36	2,408 32
295	50	à	0.43	4	73				
360	40	à	0.40	5	70				

In 4,619 cwt. 60 lbs. matte from the Halsbrückner Works, as—

Cwt. lbs. P. c. Ag. P. c. Pb. P. c. Cu.	Gold. Lbs.	Silver. Lbs.	Lead. Cwt. lbs.	Copper. Cwt. lbs.
2,583 40 à 0.29 7 69 2,036 20 à 0.29 7 73		1,339.68	323 37	3,268 97
In 21 cwt. 38 lbs. other material	0.258	8.25		18 8
In 17 cwt. 84 lbs. copper for neutralizing		0.73		17 84
In 5,373 cwt. solution from gold-separation				248 91
Total	0.258	2,552.11	444 73	5,962 12

B.—*Production.*

A, as salable material, produced—

	Gold. Lbs.	Silver. Lbs.	Lead. Cwt. lbs.	Copper. Cwt. lbs.
20,991 cwt. 26 lbs. copper-vitriol à 25.4 per cent. Cu				5,331 77
B, as intermediate products—				
1,306 cwt. 96 lbs. extraction residue, à 1.94 per cent. Ag., 41 per cent. Pb., 11 per cent. Cu	0.250	2,535.50	535 83	143 76
7,862 cwt. 25 lbs. mother-liquid for making roasting-balls = 14,295 cu. ft. à 2 lbs. Cu				285 90
C, as half-finished products, (after deduction of that taken from former year:)				
3,009 cwt. 5 lbs. solution = 5,420 cu. ft. à 3 lbs. Cu				162 60
Total production	0.250	2,535.50	535 83	5,924 3

	Gold. Per cent.	Silver. Per cent.	Lead. Per cent.	Copper. Per cent.
Amount extracted in per cent. of metal contained in material	96.90	99.35	120.48	99.36
Contained in the waste mother-liquid				4.79
Percentage of loss	3.10	0.65		0.64
Sulphur extracts			20.48*	

* The surplus of lead extracted can be accounted for by the imperfect determination of the lead in the matte. The lead lining of the tanks is also affected by the acid; sulphate of lead is formed, which settles to the bottom.

The following are the costs of treating 100 cwt. of concentrated matte for the year 1869:

A.—*Crushing and roasting.*

	Thlr.	Sgr.	Pf.
Wages for stamping and grinding the concentrated matte	3	10	
Expenses in keeping stamps and mill in repair	1	17	5
Wages for roasting	21		9
Bituminous coal	21	5	8
Repair of roasting-furnace and tools	14	16	10
Total	61	20	8

B.—*Dissolving, &c.*

	Thlr.	Sgr.	Pf.
Wages	46	16	3
Bituminous coal for heating steam-boiler, evaporating the solutions, drying the vitriol and residues, &c	32	13	10
Sulphuric acid	116	24	2
Repair of furnaces, apparatus, and tools	52	2	2
	247	26	5
Grand total, (exclusive of general costs)	309	17	1

220. *Separation of gold from silver.*—This operation consists in the treatment of the refined and granulated silver from the silver-refining furnace with concentrated sulphuric acid (66° B.,) whereby the silver is dissolved as sulphate of silver, accompanied by the disengagement of sulphurous acid, and the gold remains undissolved in the form of a fine powder. The manipulation is conducted in a cast-iron kettle, which stands over a fire-place. The kettle is about 40 inches in diameter and 50 inches deep, and is covered with a hood during the operation of dissolving; a pipe connects with the hood through which the sulphurous-acid vapors pass off into a small condensing-chamber of sheet-lead for the purpose of arresting any of the silver solution which may be carried over by the gas. There is also an opening in this hood, through which the silver adhering to the bottom and sides of the kettle during the operation, can be removed by stirring the solution. About 400 kilograms of granulate silver are treated at a time, whereby 800 kilograms of sulphuric acid are necessary. At first only 350 kilograms of sulphuric acid are added, and the remainder during the continuation of the manipulation. There is an energetic evolution of sulphurous acid during the first period of the operation; the fire, therefore, must be carefully regulated.

221. After the silver is completely dissolved, the solution is allowed to stand for ten hours in order to cool it off and clarify the liquid, the metallic gold settling to the bottom. The solution is then dipped out with copper ladles into copper vessels and carried to a tank, lined with

sheet-lead, into which it is emptied. There is sufficient water in this tank to reduce the solution to 20° B. The whole is now stirred with wooden paddles and heated by passing steam through it; the silver is then precipitated, as metallic silver, by placing sheet-copper in the solution. If, after testing the solution with salt, it has been proved to contain no silver, it is allowed to stand for ten hours, so that the solution may become clear. The copper-vitriol solution is then removed into a second settling-tank by means of a lead siphon; from here it goes to another tank, from which it is forced up into the evaporating-pans of the copper-vitriol establishment. The cement silver is sieved in a copper sieve, to free it from small pieces of undissolved metallic copper, and is then well washed with hot water in a wooden vessel that has a perforated bottom, until the wash-water gives no precipitate with chloride of barium. The wash-water contains copper and is again used n precipitating the silver. The cement silver, after having been well washed, is pressed into cakes under a hydraulic press; it is then heated in iron retorts and melted in graphite crucibles in quantities of 200 kilograms. The melted silver is poured into cast-iron molds, painted on the inside with talc; after which it is sent to the mint in the city of Dresden. It is $\frac{99.8}{100}$ fine, and contains no trace of gold.

222. The gold residue is strongly impregnated with sulphate of silver, metallic silver, and copper. It is, therefore, boiled again with hot water, whereby the sulphate of silver and copper are dissolved. The wash-water is put into the silver-precipitation tank. The gold powder from every three operations is then boiled with concentrated sulphuric acid, in two cast-iron pots, which dissolves the remaining silver and leaves the gold as free from this metal as possible. The first operation of boiling lasts eight hours, the second only one. The resulting solution is used for granulating. The gold is then washed in a porcelain vessel, with hot water, in order to remove any silver solution adhering to the gold particles, until the wash-water gives no precipitate with salt. The gold is now of a brownish-yellow color, and is dried in graphite vessels and then heated twice in small iron crucibles with bisulphate of soda, and afterward boiled in sulphuric acid. After each heating and boiling with sulphuric acid, the gold is thoroughly washed, the gold-dust is then dried and finally melted in Hessian crucibles with saltpeter, in order to separate it from platinum. The platinum slag produced is sent to the laboratory, where the platinum is extracted. After the crucible has cooled, it is broken open and the gold-button extracted; this is melted again in a graphite crucible with borax, and then poured into small molds. It possesses a fineness of $\frac{99.4}{100}$.

223. *Extraction of bismuth.*—The extraction of the bismuth is conducted according to the hurried method, whereby all ores, dross, litharge, and furnace-hearth, containing bismuth are treated. The litharge and furnace-hearth from the operation of silver-refining contain from 8 to 20 per cent. bismuth. They are all crushed and treated with hydrochloric acid

and water, in clay jars of 10 cubic feet capacity. Each 50 kilograms of hearth is treated with its equal weight of hydrochloric acid and 10 kilograms of water. The whole is well stirred, and after several hours, water is added until the jar is full to the top. After the solution has been allowed to stand for twelve hours, the fluid is drawn over into a large wooden vessel, having a capacity of 50 cubic feet, by means of a siphon. This vessel is filled with water at the same time, and the bismuth in the solution is thereby precipitated as basic chloride of bismuth in the form of a white powder, ($2\ Bi\ O_3$, $Bi\ Cl_3$.) In sixteen to twenty-four hours the precipitate has completely settled down on the bottom of the vessel, and the clarified liquid is allowed to flow out of the vessel into a large settling-basin, wherein any of the bismuth precipitate, which has been carried off by the liquid, may settle to the bottom. A fresh solution is now put into the emptied vessel, water added, and this operation repeated until it is necessary to remove the precipitate on the bottom by means of opening the lower cocks on the vessel. The bismuth precipitate is then brought upon a linen filter and is thus partially freed from the acid solution. As the bismuth solution cannot be entirely drawn out of the dissolving-vessels without stirring up its contents, a single treatment with diluted hydrochloric acid is not sufficient to extract the whole amount of bismuth contained in the products treated. The operation must therefore be repeated as long as any precipitate is formed by the addition of water. After the first solution has been removed from the dissolving-vessel, 10 kilograms more of hydrochloric acid are added and the vessel filled to the top with water, and, after the precipitate has settled to the bottom, the clarified liquid is again drawn off, &c. Generally this must be repeated from four to six times before the vessel can be cleaned out for a new portion. The bismuth salt is again dissolved in hydrochloric acid, as it still contains too much lead, and is again precipitated with water. The richer the furnace-hearth is in lead, and the poorer in bismuth, the greater is the amount of lead contained in the first precipitate, and the oftener must the process of dissolving and precipitation be repeated, as bismuth containing more than 2 per cent. lead is difficult to sell. The bismuth salt is dried in a drying-oven heated with steam, and is then smelted in a cast-iron crucible with 50 per cent. calcinated soda, 7.5 per cent. charcoal-powder, 3 per cent. glass, and reduced hereby to metallic bismuth.

224. There are sixteen dissolving and sixteen precipitation vessels at the Muldener Works, also several filtering apparatuses. From 150 to 200 kilograms of raw products are daily treated.

Products: *a.* Bismuth containing 0.06 to 0.10 per cent. = 17 oz. 0 dwt. 19.2 gr. to 29 oz. 2 dwt. silver, and 1.5 per cent. lead.

b. Residues containing about 1 per cent. bismuth; they are reduced.

The treatment of products that do not contain at least 4 per cent. bismuth is not profitable. The annual production of metallic bismuth at the Freiberg smelting-works amounts to about 2,500 kilograms.

225. MACHINES, FURNACES, AND APPARATUS AT THE FREIBERG SMELTING-WORKS.

(1.) MULDENER AND HALSBRÜCKNER WORKS.—*Machines:* 6 vertical water-wheels, 4 turbines, and 6 steam-engines, of 140 horse-power, for driving 6 cylinder blowers, 2 ventilators, 4 stamp-mills with 46 stamps, 2 ore-grinding machines, 2 sieve machines, 1 rolling-mill, 3 force-pumps, and 15 forges with various tool-machines.

Roasting-apparatus: 18 roasting-stalls connecting with large subterranean canals, 8 thribble and 5 double agglomerating roasting-furnaces, 1 single-hearth and 6 double-hearth reverberatory roasting-furnaces, and 2 muffle furnaces.

Smelting-apparatus: 5 blast-furnaces with 8 tuyeres, 6 blast-furnaces with 4 tuyeres, 7 smelting reverberatory furnaces, 4 cupellation-furnaces, 2 silver and 5 lead refining furnaces, 3 lead-liquating furnaces, 2 silver-smelting furnaces, and 43 kettles in the Pattinson establishments.

Sublimation-apparatus: 1 arsenic-sublimation furnace at the Halsbrückner Hütte.

Condensing-apparatus: above and under ground condensing-chambers, with canal connections of: 203,464.7 cubic feet = 4,620.86 cubic meters' capacity for the roasting-furnaces; 143,772.8 cubic feet = 3,265.21 cubic meters' capacity for the blast-furnaces; 346,425.0 cubic feet = 7,867.61 cubic meters' capacity for the reverberatory furnaces; 36,487.0 cubic feet = 828.65 cubic meters' capacity for the cupellation-furnaces and lead and silver refining and liquation furnaces. The total capacity of all the condensing-chambers, therefore, amounts to 730,149.5 cubic feet, or 16,582.33 cubic meters.

Extraction-apparatus: a copper-extraction apparatus, with 8 dissolving-vessels for copper-matte and vitriol, vitriol-crystallizing tanks having a capacity of 16,248 cubic feet, or 369 cubic meters, at the Halsbrückner Hütte, and a bismuth-apparatus of 12 dissolving-vessels, and several precipitating-vessels of 768 cubic feet, or 17.44 cubic meters' capacity at the Muldener Hütte.

Other arrangements: 1 self-acting inclined plane, and 8 hoisting-apparatuses, with 7,000 meters of tram-way connections at both works.

(2.) GOLD-SEPARATION ESTABLISHMENTS AT HALSBRÜCKNER WORKS: 1 gold-separating-apparatus, with one cast-iron dissolving-kettle, having a capacity of 27 cubic feet, or 613 cubic decimeters, and three precipitating-vessels of 185 feet, or 4.2 cubic meters' capacity.

(3.) MULDENER ZINC-WORKS: 3 long reverberatory roasting-furnaces, 3 distillation-furnaces, constructed according to Siemens's regenerative system, and one zinc-refining furnace.

(4.) AT THE MULDENER ARSENICAL WORKS: 8 distillation tubular furnaces for realgar, and 3 galley-furnaces, 2 clarifying-furnaces, 2 sublimation roasting-furnaces, and 20 white arsenical-glass furnaces.

(5.) SULPHURIC-ACID MANUFACTORIES OF BOTH WORKS.—*Machines:* 1 turbine and 4 steam-engines, having a total of 26 horse-power; they

charge the Gerstenhofer roasting-furnaces, and force the acid up over the precipitating-tower, &c.

Roasting-apparatus: 21 kilns and 12 Gerstenhofer roasting-furnaces.

Condensing-apparatus: 8 condensing-chambers, having a capacity of 118,087 cubic feet, or 2.681.86 cubic meters, and 6 lead-chamber systems, composed of 19 lead-chambers having a capacity of 710,043 cubic feet, or 16,125.69 cubic meters.

(6.) OTHER APPARATUS: 3 precipitating-towers, with four sulphureted-hydrogen generators for purifying the acid, 8 lead-evaporating pans, 3 platinum-stills, 4 nitric-acid apparatuses, and 3 iron-vitriol-evaporating apparatuses with crystallizing-tanks, having a total capacity of 4,302 cubic feet, or 97.70 cubic meters.

(7.) METAL-WARE MANUFACTORY: 1 shot establishment, with a shaft 61.4 meters deep, 2 lead-pipe presses, 1 lead-rolling machine, and 1 lead-wire machine, driven by 2 vertical water-wheels of 11-horse power.

(8.) CLAY MANUFACTORY: one 10-horse power steam-engine for running a 6-stamp crushing-mill, 1 grinding-mill, 1 kneading-machine, 2 hand brick-presses, and 1 clay-baking furnace.

(9.) BRICK MANUFACTORY: 2 brick-burning furnaces, with drying arrangements.

226. PRODUCTION OF THE SAXON MINES AND THE FREIBERG METALLURGICAL WORKS IN 1871.—Ore mined in Saxony and treated at Freiberg:

	Kilograms.	Value. Thaler. Sgr.
Mined in the Freiberg district	27,357,025	1,706,392 26
Mined in other Saxon districts	58,250	4,393 29
Total	27,415,275	1,710,786 25

Which contained:

	Kilograms.
Gold	0.116
Silver	26,286.907
Lead	4,320,046.250
Copper	44,865.300
Zinc	267,650.500
Cobalt and nickel	129.500
Arsenic	285,520.000
Sulphur	2,915,876.000
And a small amount of bismuth	
Total	7,860,374.573

The above value of the ores is calculated as follows:

Thaler. Sgr.	
1,402,436 24	paid according to the ore-tariff.
36,293 12	supplementary payment for lead, copper, zinc, and arsenic, (vide ore-tariff in appendix.)
272,056 19	supplementary payment of the half of clear gain.
1,710,786 25	

The men employed in the mines of the Freiberg district are: mine officials, 279; clerks, 50; laborers in mines and dressing-works, 7,343; total, 7,672. This includes 263 boys, under eighteen years of age, employed in the mines, and 401 boys employed in the dressing-works, and also 575 irregular laborers.

227. PRODUCTS OF THE FREIBERG METALLURGICAL WORKS, 1871.

	Kilograms.	Value. Thaler. Sgr.
Gold	54. 83150	50, 710 27
Silver	31, 071. 70400	1, 850, 002 28
Lead-products, viz:		
Soft and hard lead, litharge, and fumes	3, 711, 845	431, 587 28
Shot	94, 611. 5	13, 535 09
Sheet-lead	291, 638. 5	38, 288 08
Lead pipes, wire, &c	315, 610. 5	44, 986 06
Copper-vitriol	1, 537, 200	227, 004 24
Bismuth	3, 213	25, 281 03
Nickle-matte	9, 540	3, 135 01
Zinc and zinc oxide	237, 214	26, 771 07
Different grades of sulphuric acid	10, 218, 613. 5	224, 774 15
Chemical products, viz:		
Iron-vitriol, soda-sulphate, nitric acid, &c	397, 709. 5	9, 028 00
Arsenical products, viz:		
Metallic arsenic, arsenious acid, oripiment, &c	1, 125, 834. 5	92, 829 21
	17, 974, 156. 53550	

Total, 359,483.65 centner, valued at 3,037,935 thaler 22 silbergroschen. The employed were:

	Officials.	Regular laborers.	Irregular laborers. Men.	Irregular laborers. Women.	Total.
Muldener smelting-works with bismuth extraction	8	420	178	22	628
Muldener zinc-works	....	19	5	1	25
Muldener arsenic-works	2	36	5	1	44
Muldener sulphuric-acid manufactory	3	77	6	.....	86
Muldener fire-clay material manufactory	....	9	4	.....	13
Halsbrückner smelting-works, with the copper-vitriol manufactory and gold-separation establishment	9	319	81	2	411
Halsbrückner sulphuric-acid manufactory	2	38	7	3	50
Halsbrückner lead-pipe, &c., manufactory	....	7	.....	8	15
Shot manufactory in Freiberg	1	2	1	.....	4
Total	25	927	287	37	1, 276

228. THE HARZ.—The smelting-works of the Upper and Lower Harz were represented by statistical charts, plans of furnaces, and a complete and systematically arranged collection of ores, metallurgical, intermediate, and final products. The latter were displayed in the following groups:

I.—LEAD-SMELTING.

a. Ore-smelting.—Products from Clausthal: slag, matte, and silver-lead
b. Matte-smelting.—Products from Clausthal: raw matte from ore and matte smelting, matte roasted in shaft-furnaces and in heaps.

II.—DESILVERIZATION OF SILVER-LEAD.

a. Zinc-desilverization.—Products from Lautenthal: skimmings, (abzug,) zinc-scum, (silver-zinc alloy;) the same from which the lead has been liquated, (zinc-dust;) poor and rich oxides; fumes from condensation-chambers; poor, antimonial, and enriched lead.
b. Cupellation.—Products from Lautenthal: abzug, abstrich, red litharge, and silver.
c. Silver-refining.—Products from Lautenthal: piece of cupellation-hearth impregnated with rich litharge and fine silver.

III.—COPPER-SMELTING.

Products from Altenau: concentrated copper-matte and black copper.

IV.—BLACK-COPPER DESILVERIZATION.

Products from Altenau: copper-vitriol and cement-silver.

V.—MANUFACTURE OF ARSENICAL PRODUCTS.

Products from Andreasberg: White arsenical glass, realgar; also beautiful and perfect crystals of arsenious acid and arsen-sulphide. These were formed in roasting arsenical ores in free heaps. This collection was intended to illustrate the processes as conducted at the above works, and to show how the various operations are divided between the four works in the Upper Harz. As the lead-smelting is conducted at all the works in the Harz according to the same process, with only unimportant variations, one description may serve the present purpose. The intermediate and secondary process will be considered as they are performed at each work.

229. THE HARZ PROCESSES.—The first smelting-process in the Harz was performed by roasting the ore in free heaps and then smelting in low furnaces. The large metallic loss through volatilization in roasting, smelting, and through the formation of slag containing 15 to 20 per cent. of lead, caused the introduction of the iron-precipitation process at about the commencement of the present century. This process has

been practiced ever since, but has, in the last few years, been greatly improved. As this process was conducted about fifteen years ago, the loss in lead was 8 to 9 per cent., and when the percentage of blende in the ore was large the loss increased to 12 per cent., in addition to 10 per cent. loss in cupellation. In order to avoid this and the large consumption of metallic iron, a series of experiments were made with reverberatory furnaces, but the large quantity of silica contained in the ore rendered the English, and even the French, processes inadvisable, if not impossible. The following experiments were then made, with intention to find a suitable substitute for metallic iron, which was found to greatly increase the melting expenses.

230. The ore (slimo) was roasted in reverberatory furnaces and smelted with iron-tap cinders, but gave poor results. High shaft-furnaces were next experimented with. Lime, iron, tap-cinder, iron-ore, and slag from the smelting of matte were each in turn used, but not found to be a desirable substitute. Lime, iron, tap-cinder, and iron-ore also gave poor results in low furnaces. It was next attempted to use the slags from the smelting of pyritous ores in the Lower Harz. These were rich in iron, and had been accumulating for many years. These experiments were conducted in a Rachette furnace, which had already been erected at Altenau. The iron was therein reduced, and was found to act even more energetically than when charged in the form of a metal. It is now known that iron, when reduced from its sequioxide, or protoxide, decomposes lead-sulphide most energetically, as it then acts in a *statu nascenti*. The resulting matte is, in a well-conducted temperature, consequently poorer in sulphur than when metallic iron is used; and iron-protoxide, by taking the place of lead in the slag, prevents a greater loss of the latter. The iron protoxide contained in the copper-slag also serves to slag the silicic acid of the ore. The Lower Harz copper-slags have, according to Streng, the following composition:

	Per cent.	
Silica	17.06	
Alumina	3.21	
Iron protoxide	70.05	= 54.5 per cent. of iron.
Copper protoxide	1.84	
Lime	3.32	
Magnesia	1.06	
Manganese protoxide	0.30	
Zinc and cobalt oxides	1.26	
Sulphur	1.65	
	97.75	

231. This highly important change was again improved in 1869, by substituting roasted lead-matte for a part of the copper-slag. Although the original intention was only to do away with the first

matte-smelting, it has given such satisfactory results, that it has been continued for other reasons. By too large an addition of lead-matte, a continual process is maintained, and the copper contents of the silver-lead, as well as the matte, is increased. In order to diminish the percentage of copper in the silver-lead, it was found necessary to decrease the amount of roasted lead-matte added to the charge to 28 per cent., and again raise the quantity of copper-slag in proportion. The smelting-expenses have been reduced, by the substitution of roasted lead-matte for a portion of the copper-slag, from 18 to 15 thaler per 1,000 kilograms ore. This saving is partially owing to the avoidance of the first matte-smelting.

232. The recent experiments made at Clausthal in the construction of shaft-furnaces, and the working of the same, are not only very interesting, but, as the results were obtained after carefully conducted trials, reliable both in a scientific and a practical economical point of view. The nature of the ores and character of the process must, however, be borne in mind. One Rachette furnace was first built in Altenau, and soon after three were built in Clausthal and two in Lautenthal. Almost immediately after the Pilz furnace had been built in Freiberg, Herr Kast, of Clausthal, erected furnaces similar in principle, but smaller, with a fore-hearth (sumpf) and fewer tuyeres. The campaign in these furnaces has lasted over three years. The economical results have been so good, that they have, after comparative trials, entirely superseded the Rachette furnace at Clausthal. The old Rachette furnaces at Clausthal were all, except one, converted into round furnaces. This was accomplished by placing a dividing wall through the center of the furnace, connecting the two long sides, and then making circles of the squares formed by the walls. One Rachette furnace is retained unaltered at Clausthal, for the purpose, as the author was informed by the director, of convincing unbelievers that it is far inferior to the round furnace. The first four round furnaces built at Clausthal* were 6.3 meters high and 0.94 meters diameter at the tuyeres, but were, respectively, 1.25, 1.41, 1.49, and 1.57 meters diameter at the top.

233. A series of trials proved that in proportion as the furnace is widened toward the top, the metallic volatilization and consumption of fuel decrease, the charge also is better prepared upon entering the smelting-zone, and the campaigns are longer. The trials in the above-mentioned furnaces gave the following results:

Width of top, meters	1. 25	1. 41	1. 49	1. 57
Metallic volatilization, meters	2. 8	2. 7	1. 7	1. 1
Consumption of coke for 100 kilograms ore, kilograms	42. 39	41. 85	41. 74	41. 62
Average length of time for smelting 100 kilograms ore, hours	73. 2	71. 8	71. 2	69. 2

* The date of the experiments in the construction of shaft-furnaces is taken from Dr. Wedding's communication in the *Preussische Zeit-Schrift*.

The consumption of coke under the same circumstances in the Rachette furnace was 44.3 kilograms; the length of time for smelting 100 kilograms ore was ninety-three hours. The shaft of a furnace was widened still more than 0.94 : 1.57 meters at the top, but the maximum proportion was here exceeded, as was shown by the charge sliding only with difficulty down the plane, which approached the horizontal; and the layers of fuel and charge became from the same cause indiscriminately mixed before entering the smelting-zone.

234. A free standing furnace, with eight tuyeres, similar to the Pilz furnace, was built in 1869. It was 7.2 meters high, 1.41 meters diameter at the tuyeres, and 2.04 meters at the top. It was a crucible-furnace, and had three tapping-hearths and two cast-iron slag-spouts. The tuyeres were 37 centimeters above the slag-spout, and 55 centimeters apart. The furnace-fumes were caught in an iron funnel suspended in the furnace, and after passing through a canal 48.3 meters long, escaped through a chimney 12.5 meters high. This furnace cost 5,900 thaler.

When it was first put in operation, the charge was similar to that in the other round furnaces, with an addition of slag from matte-smelting, but the slag produced was so pasty, that it could not be tapped; nor was slag of the right character obtained by increasing the quantity of matte-slag and decreasing the ore in the charge. In the next trial, the slag from the copper-ore smelting was entirely omitted. The resulting silver lead and matte were of the same nature as that from the other furnaces, but the slag, owing to an imperfect fusing, was very rich in lead, containing it both chemically combined and mechanically mixed as undecomposed lead-sulphide. The next idea was to produce a small amount of slag; and with this object in view, only 30 kilograms of copper-slag was charged to 100 kilograms ore and 50 kilograms lead-matte. The blast was made as strong as possible, 24 millimeters, quicksilver column, but even then the charge was not sufficiently fusible, and salamanders were soon formed, obstructing the smelting-process. The conclusion was now reached that the diameter of the hearths, or smelting-zone, was too large for a process of this character, as the temperature herein produced was not high enough to cause a perfect reaction and separation of the different products. The furnace-hearth was therefore decreased to 1.25 meters diameter, but a round ball solidified in the center of the hearth, which was not removed, by increasing the proportion of slag in the charge, narrowed the pressure of blast. Four of the eight tuyeres were then projected 16 centimeters in the hearth, leaving a circle about 1 meter in diameter. The furnace thereupon worked well, and gave equally good results with the other round furnace.

According to the information derived from Herrn Kast, the director of the Clausthal (Frankenscharn) Smelting-Works, and after whom the round furnace with four tuyeres was named, two furnaces with four tuyeres perform one-third more work with an equal number of work-

men and a like quantity of fuel than one round furnace with eight tuyeres.

235. In order to determine the effects of an equal quantity of wind under different pressure of blast, the diameter of the blast-nozzles was increased in one of the furnaces with four tuyeres from 43 millimeters to 61 millimeters, with the following results:

	Nozzle 61 millimeters in diameter.	43 millimeters in diameter.
Charge:		
Ore, kilograms	1,000	1,000
Roasted matte, do	510	510
Copper-slag, do	1,260	1,260
Ore-slag, do	330	330
Fuel:		
Cokes, do	490	490
Products:		
Silver-lead, do	580	580
Lead-matte, do	750	800

Contents of silver-lead.... 0.15 per cent. = 43 oz. 13 dwt. 14 gr. silver.
Contents of lead-matte.... 0.27 per cent. = 78 oz. 14 dwt. 4 gr. silver.
Contents of lead-matte.... 8.5 .... 8.4 per cent. lead.
Contents of slag.......... 0.4 .... 0.4 per cent. lead.

Length of time in smelting 1,000 kilograms ore, 6.8 to 7.6 hours. Pressure of blast, 16.24 millimeters mercury column. The consumption of fuel was the same in both cases. The quantity of slag in the furnace with wide was smaller than in the furnace with narrow nozzles, but the furnace worked much better; the formation of furnace accretions was diminished, and the smelting-time was shorter, giving the furnace an increased capacity. Blast-nozzles with 61 millimeters diameter have since been adopted.

236. The known fact that heated blast serves in iron blast-furnaces to concentrate the heat, increase the capacity of the furnace, and saves fuel, induced the officials at the Clausthal works to try the effect of heated blast on lead-smelting. Two round furnaces with four tuyeres were employed in making the experiment. One was worked with cold blast, the other with blast heated to 140° to 180° C. These trials proved that heated blast is not advantageous for lead-smelting, for the products from two operations were similar, both in quantity and quality, while the value of the small quantity of cokes saved in the charge was surpassed by the value of the coal consumed in heating the blast.

237. In order that each process might be more perfectly and economically carried out, the government authorities have been making, as far as practicable, a separation of the different metallurgical operations performed in the utilization of the ores extracted in the Harz Mountains.

This plan is now nearly completed. Clausthal was selected as the central works for smelting lead-ores, Lautenthal for desilverizing the silver-lead, and Altenau for the treatment of copper-ores and products. Argentiferous lead-ores and foreign silver-ores are smelted at Andreasberg; the rich silver-lead is cupelled; the poor is sent to Lautenthal.

238. LEAD-SMELTING AT CLAUSTHAL.—The ores are composed of galena, copper (and iron) pyrites, blende, and small quantitiesof silver-ores. The gangue is calcit, quartz, siderit, argillaceous slate, and baryte. An average analysis presents the following composition:

71.68	per cent. sulphide of lead.
0.91	per cent. sulphide of copper.
1.98	per cent. sulphide of zinc.
4.14	per cent. carbonate of protoxide of iron.
0.54	per cent. tersulphide of antimony.
1.41	per cent. protosulphide of iron.
0.113	per cent. sulphide of silver.
15.24	per cent. silicic acid.
0.15	per cent. alumina.
2.38	per cent. carbonate of lime.
1.46	per cent. sulphate of baryte.
0.08	per cent. magnesia.
100.083	

239. It has already been mentioned that the present iron-precipitation process is an important improvement on that method as formerly practiced, inasmuch as the first matte-smelting has been done away with, and while the quantity of basic copper-slag added to the charge is diminished, a correspondingly large quantity of roasted lead-matte is charged in its place. The process is now called the "combined ore (schlieg) and matte smelting." The furnaces for ore-smelting are all round; one Rachette furnace making an exception. They all have a fore-hearth, (sumpf,) and the slag runs continually from the fore-hearth down an inclined bank made of brasque and sand. That portion of the slag which congeals on or near the fore-hearth, is rich in mechanically-mixed metals, and is resmelted; the rest is thrown away, as it contains only about 1.5 per cent. lead.

240. The charge and fuel (coke) are charged in alternate horizontal layers. This change has given excellent results, compared to the old method of charging in vertical sections. Formerly the slag contained 2 to 3 per cent. and the matte 15 to 20 per cent. lead, but at present the slag produced contains only 1 to 2.5 per cent. and the matte 8 per cent. lead, and this matte contains so little lead that it can be roasted in shaft-furnaces without sintering, as the pressure of blast is not allowed to exceed 22 millimeters mercury column. The metallic volatilization and the formation of salamanders is favorably reduced.

Dr. Wedding gives the average charge for 1871 as—

1,000	kilograms ore.
650	kilograms copper-slag from Lower Harz.
510	kilograms roasted matte.
12.1	kilograms sweepings.
10.5	kilograms fumes.
5.5	kilograms lead-flux.
20	kilograms copper-slag from black copper smelting.
430	kilograms rich slag from matte-smelting.
470	kilograms slag from same operation.
3,108.1	kilograms.

241. The consumption of fuel per 1,000 kilograms ore, including the powdered charcoal for brasque and charcoal used in blowing in the furnace, was 451.7 kilograms coke and 25.5 kilograms charcoal. The result per 1,000 kilograms ore is, *a*, 587.7 kilograms silver-lead, and *b*, 760.9 kilograms matte, 510 kilograms of which are roasted and added to the next charge. The charge in the autumn of 1873 was composed of 100 kilograms ore; 94 kilograms copper-slag; 30 kilograms roasted matte; 44 kilograms slag from same operation; 25 kilograms slag from matte-smelting; 2 kilograms lead-flux; 89 kilograms coke.

The following are the average analyses of the products from the above charge:

Silver-lead.	Per cent.	Matte.	Per cent.	Slag.	Per cent.
Lead	98.970	Sulphur	29.55	Silicic acid	43.60
Antimony	0.618	Iron	55.72	Alumina	15.50
Copper	0.275	Lead	7.98	Iron protoxide	31.68
Silver	0.127	Copper	4.39	Lime	6.50
Zinc	0.008	Zinc	1.12	Magnesia	1.56
Iron	0.002	Silver	0.03	Lead oxide	0.70
		Antimony	0.35	Silver	0.008
	100		99.14		99.548

The slag is added to the charge of ore and matte smeltings. The silver-lead is sent to Lautenthal for desilverization. The matte is broken and repeatedly roasted in free heaps until it contains about 5 to 7 per cent. sulphur. That small portion of the roasted matte which is not added to the charge of smelting is smelted in low shaft-furnaces, with slag from the ore-smelting and a small quantity of iron. The products are: *a*. Silver-lead. This is on account of a large percentage of copper, which disqualifies it for the zinc-desilverization process, cupelled at Clausthal. *b*. Copper-matte, containing 12 per cent. of copper and 0.02

to 0.03 per cent. = 5 oz. 16 dwt. 14.4 gr. to 18 oz. 14 dwt. 19 gr. silver; this is equal in quantity to about one-third of the lead-matte which was charged. *c.* Slag, having the following composition:

	Per cent.
Silicic acid	29.25
Alumina	13.95
Iron protoxide	48.60
Lime	5.85
Magnesia	0.71
Lead oxide	0.57
Copper oxide	0.10
Silver	0.00066
Total	99.03066

The copper-matte is broken, roasted in free heaps, and smelted for black copper in a spectacle-furnace, with slag from the smelting of pyritous ores, whereby the greater part of the iron sesquioxide and oxides of other base metals are slagged, and a small portion of the copper oxide reduced to black copper. The larger part combines with sulphur, which is reduced from sulphate salts and forms the matte. Lead acts in a similar manner, a part taking up silver and forms silver-lead. The silver also enters the black copper and copper-matte. The black copper, containing small quantities of lead and silver, is sent to Altenau for desilverization. The copper-matte, containing from 24 to 40 per cent. copper, is repeatedly roasted, and smelted as above. The slag, containing 0.5 to 1.0 copper, is added to the charge in the ore-smelting.

242. There are at present employed in Clausthal:

	Tuyeres.	Capacity in 24 hours.
1 round free-standing furnace	8	13,500 kilograms' charge.
1 round free-standing furnace	4	9,000 " "
3 round Kast furnaces	4	7,500 " "
4 round Kast, being altered to Rachette furnaces	5	7,500 " "
1 Rachette furnace	12	11,000 " "
2 low shaft-furnaces	3	3,750 " "
1 spectacle-furnace	2	2,500 " "
Total	38	54,750 " "

243. ALTENAU.—The treatment of copper-ores and products form the basis of the process at Altenau. But a small quantity of lead-ore is smelted.* The former principally consists of copper pyrites, and are of secondary importance; they are only produced in small quantities, and contain such a small amount of silver that they could not be treated with profit alone, according to the German metallurgical copper process. The resulting copper from this process contains from 0.005 to 0.017 per cent. silver (1 oz. 9 dwt. 3.84 gr. to 4 oz. 19 dwt. 0.48 gr. per ton) when sent to

* Herrn Kühleman's communication in the *Prussische Zeitscrift* is freely used in treating of the Altenau process.

market. The lead-ores principally consist of argentiferous galena, which is associated with small quantities of siderite, zinc-blende, copper pyrites, iron pyrites, and tetrahedrite.

An average lead-ore mixture in 1869 contained—

	Per cent.
Lead	63.320
Silver	0.096
Copper	0.750

244. The lead-ore is smelted according to the iron-reduction process. It is conducted entirely in Rachette furnaces since 1864, and in the same manner as at Clausthal; the charge is varied only on account of bases or acids in the ore, &c.

245. The products of the operation of ore-smelting are: *a*, silver-lead; *b*, slag; and *c*, lead-matte. The silver-lead contains, on an average, 0.13 per cent. = 37 oz. 16 dwt. 19.2 gr. silver, and is sent to Lautenthal for desilverization by means of zinc. The slag contains from $\frac{3}{4}$ to 1 per cent. lead and 0.00087 per cent. silver, (5 dwt.;) part of it is thrown away, and a part is used over again in the same operation as flux. The lead-matte contains, from the period 1866 to 1869, when slag from ocher was used entirely as a precipitating medium, the following amount of—

	Per cent.
Lead	11.5
Copper	4.0
Silver	0.034

Since the adoption of the combined ore and matte smelting, the percentage of copper has increased and that of the lead decreased.

a. Lead-matte from smelting with copper-slag from ocher toward the close of 1866, Dr. Streng analyst.

b. Lead-matte from combined ore and matte smelting, Herr Hillgrist analyst.

	a. Per cent.	*b*. Per cent.
Lead	10.88	11.5
Copper	3.83	5.2
Silver	0.03	0.033
Iron	55.90	57.2
Zinc	1.13	Not determined.
Antimony	0.27	Not determined.
Sulphur	26.67	22.3

246. The lead-matte is roasted twice in shaft-roasting furnaces, 3 to 3.5 meters high and 1.17 by 1.46 meters wide, during which operation it loses all its sulphur to within 7 per cent. The sulphurous acid is used for the manufacture of sulphuric acid.

The roasted lead-matte is further treated in the older matte-smelting blast-furnaces, which are $2\frac{1}{2}$ meters high, also in the old ore-smelting blast-furnace having one tuyere and which are 6 meters high. The

smelting is conducted with a nose, and ore-slag is used for flux. Coke is the fuel used.

247. The products of this operation are *a*, silver-lead; *b*, slag; and *c*, lead-matte. The silver-lead contains 0.19 per cent.=55 oz. 6 dwt. 19.2 gr. silver, and a considerable amount of copper is directly cupelled. The matte-slag, containing 2 per cent. lead and 0.002 per cent.=11 dwt. 15.84 gr. silver, is used in other operations as a flux, especially in the operation of ore-smelting. The lead-matte, which has become much poorer in lead and richer in copper is resmelted in the same furnace.

248. In this second treatment of the lead-matte the same products again result; the matte, however, is much richer in copper. As soon as it contains 20 per cent. of copper by further smelting, it is delivered over to the operation of the smelting of copper-products, (*Krätz kupferarbeit.*)

249. Formerly from three to four smeltings were necessary to concentrate the matte up to 20 per cent. copper, but since the ore-smelting has been conducted in Rachette furnaces, with slags rich in iron as fluxing-material, only two smeltings of the matte were necessary; and since the adoption of the combined ore and matte smelting, only one smelting has been necessary.

The average contents of lead-matte in 1869 from the first smelting was in—

	Per cent.
Silver	0.043
Lead	10.000
Copper	11.000

From second smelting:

	Per cent.
Silver	0.056
Lead	10.000
Copper	21.000

That produced in 1870 from first concentration contained—

	Per cent.
Silver	0.057
Lead	15.000
Copper	14.000

In smelting the matte a large amount of products resulting from other manipulations are always added to the charge, such as furnace-fumes, furnace-dross, slimes, argentiferous and cupriferous dross, refining-dross, lead-scraps, and slag containing lead oxide from the operation of litharge-reduction.

250. *Treatment of copper-products.*—The matte now containing about 20 per cent. copper is subjected to this operation, which has for its sole

object the extraction of the silver and copper from the matte. Formerly the matte contained on an average—

	Per cent.
Copper	20 to 22
Silver	0.035 to 0.055
Lead	9 to 10
Iron, about	40
Sulphur, about	20

The matte produced at present from one smelting contains—

	Per cent.
Sulphur	21.6
Iron	39.2
Copper	13.7
Lead	15.0
Silver	0.057

251. The copper-matte is roasted several times and then fused for black copper. Although it has been proved by experiment that this matte can be well roasted in furnaces, it is not desirable to do so, as the roasting-furnaces are all in use for roasting the lead-matte, and these supply the sulphuric-acid chambers with a sufficiency of sulphurous acid; so all copper-matte is at present roasted in heaps under cover. The heaps must be turned seven or eight times in order to effect a proper roasting of the matte. This requires from five to six weeks. The sulphur is reduced from 20 per cent. to 6 or 8 per cent.

252. The roasted copper-matte is fluxed with slag from the smelting of copper pyrites and smelted in blast-furnaces. The blast-furnaces are 3.22 meters high, have a width of 0.88 by 1.02 meters, and have one tuyere only. About 4,500 kilograms of copper-matte ore are smelted in twenty-four hours. The campaign lasts about one month.

a, Silver-lead; *b*, black copper; *c*, copper-matte; and *d*, slag, are the resulting products of the first copper-matte smelting.

The black copper resulting from the first smelting is a very impure product; it contains a large percentage of lead and also silver. It is mixed with the black copper produced from the next smelting and smelted with it, in the following manipulation. The copper-matte contains:

	Per cent.
Copper	40.00
Iron	30.00
Sulphur	20.00
Silver	0.08

253. The matte is again roasted several times and re-smelted in shaft-furnaces, whereby the same products are produced as before.

The following third, fourth, and fifth mattes are heated in the same

manner—black copper always being produced, while the copper-matte becomes richer in copper and poorer in iron.

The copper-matte smelting from the fifth smelting is not further treated until the following year, as only a small quantity is produced. Five separate smeltings, accompanied with repeated roasting, are necessary to extract the copper from the copper-matte containing 20 per cent. of copper in the form of black copper. The average amount of flux employed in the five smeltings per 100 cwt. of copper-matte is 75 cwt. of slag from the operation of pyrites-smelting, and 20 cwt. of slag from the same operation.

254. Analyses of slags from the smelting of copper-products: *a*, slag from first smelting of the concentrated matte, or second smelting of copper-matte, by Hahn; *b*, slag from third smelting of copper-matte, Werlisch; *c*, slag from fourth smelting of copper-matte, by Hahn; *d*, slag from fifth smelting of copper-matte, by Werlisch.

	a	*b*	*c*	*d*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silicic acid	27. 565	33. 202	29. 099	30. 994
Antimony oxide	0. 977	0. 235	0. 254	0. 196
Iron protoxide	54. 277	55. 915	60. 513	58. 605
Copper protoxide	1. 408	0. 682	2. 067	0. 933
Lead oxide	4. 771	2. 120	0. 431	0. 021
Lime	4. 105	3. 763	1. 475	4. 314
Magnesia	0. 565	0. 594	0. 588	0. 253
Alumina	6. 498	4. 388	4. 275	5. 732

Such slag as contains entangled matte is only employed again as a flux in the operation of copper-matte smelting; the remainder is used in the ore-smelting, where it performs the same service as the slags from Oker.

255. The following are analyses of the copper-matte resulting from the various smeltings: *a*, matte from first smelting, by Hillegeist; *b*, matte from second smelting, by Hahn; *c*, matte from third smelting, by Werlisch; *d*, matte from fourth smelting, by Hahn; *e*, matte from fifth smelting, by Werlisch.

	a	*b*	*c*	*d*	*e*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphur	21. 000	19. 968	17. 668	18. 156	19. 667
Antimony	0. 200	0. 444	1. 012	0. 464	0. 211
Iron	29. 200	8. 122	8. 638	0. 993	1. 062
Copper	37. 000	63. 916	72. 743	80. 774	80. 322
Lead	13. 000	7. 286	0. 641	....	....
Silver	0. 075	....	....	....	....

256. *Refining of the black copper.*—Before the black copper obtained from the foregoing operation is desilverized, it undergoes a process of oxidizing-smelting, in order to free it from its foreign elements. The black copper obtained from all five smeltings is so mixed, that the

charge will contain about 0.16 to 0.20 per cent. = 46 oz. 12 dwt. to 58 oz. 6 dwt. silver, and 80 to 83 per cent. copper. The operation is conducted in a large refiningfur-nace. The hearth is round, and has a diameter of 2.92 meters; it is composed of brasque and pulverized argillaceous slate.

257. A charge consists of 45 to 48 cwt.; wood was formerly used as fuel, but at present, bituminous coal is also made use of, with the employment of blast under the fire-grate. About five hours are necessary to melt the black copper, and after the slag has been removed, the blast is turned on. At first only a small pressure is used, but after about two hours it is increased, so that 7½ cubic meters pass into the furnace per minute. The impurities contained in the black copper are eliminated by the oxidizing influence of the blast. The entire process lasts from sixteen to eighteen hours. The copper is immediately granulated when tapped from the furnace. It contains from 91 to 97 per cent. copper and 0.20 to 0.40 per cent. = 58 oz. 6 dwt. to 116 oz. 12 dwt. silver.

258. The following is an analysis of the refined copper:

	Per cent.		Per cent.
Iron	0.070	Silver	0.300
Lead	2.710	Copper	95.000
Nickel, Cobalt, Zinc	0.048	Antimony	1.530
		Arsenic	Trace.

The resulting slags are of two kinds; that which is formed during the first part of the process is only a partially-melted mass; it is rich in iron, cobalt, and nickel-oxide; the other which forms during the latter part of the process, is thin fluid, and rich in lead. As their further manipulation is different, they are kept separate. The small amount of slag obtained of the first sort, is smelted with arsenical pyrites and baryte for nickel speiss. It is sold in this state. The other slag is smelted with slag from the matte-smelting in blast-furnaces; black copper, rich in lead and silver, and slag rich in copper and lead, are the resulting products. Some silver-lead is obtained from the black copper by its liquation. This silver-lead contains on an average 0.0775 per cent. = 22 oz. 11 dwt. 22.46 gr. silver and many impurities. The liquated copper still contains much lead, and is refined in the same manner as the original copper. The resulting granulated copper is much poorer and impurer than that obtained from the original copper, and contains 43 oz. 14 dwt. silver and 90 to 93 per cent. copper. The resulting slags are much richer in nickel and cobalt than the other slag from the main operation; they are smelted for nickel speiss.

259. The slags from the operation of slag-smelting in the litharge-reduction furnaces, containing about 5 per cent. copper, from 6 to 10 per cent. lead, and 0.00125 per cent. = 7 dwt. silver, are charged in with the lead-ore smelting charge for the extraction of their metallic con-

tents. The chemical composition of the last slags will be seen from the following analyses: *a*, slag from slag-smelting, by Hahn; *b*, slag formed during the first period of the operation of refining the copper resulting from slag-smelting, by Werlisch; *c*, slag from second period of same operation.

	a	*b*	*c*
	Per cent.	*Per cent.*	*Per cent.*
Silicic acid	36.584	14.767	20.811
Arsenic acid	....	Trace...	....
Antimonious acid	0.092	...do....	0.177
Iron protoxide	33.918	...do....	2.677
Copper protoxide	1.756	11.211	6.222
Lead oxide	10.974	37.693	60.930
Nickel protoxide, Cobalt protoxide, Zinc oxide, Manganese protoxide	1.671	28.872 4.556	1.216
Lime	4.087	0.423	0.560
Magnesia	1.370	0.130	0.356
Alumina	9.302	1.849	6.068
Sulphuric acid	....	....	0.431
	99.754	99.501	99.448

260. *Extraction of silver from copper, and manufacture of vitriol.*—After the black copper has been refined and granulated, it is treated with sulphuric acid for the purpose of its desilverization, whereby copper-vitriol is also produced. There are two establishments at Altenau for the manufacture of vitriol; one was built in 1864, the other in 1868.

The older has three dissolving-vessels and one evaporating-pan; the new has six dissolving-vessels and two evaporating-pans. The dissolving-vessels are of wood lined with sheet-lead. They are 1.02 meters square and 1.17 meters high. They have a double bottom. The upper or false bottom is perforated with holes 0.025 meter in diameter.

261. When the dissolving-boxes are charged with copper, about one-fourth of the charge, in large pieces, is laid on the false bottom, and on the top of this the small copper granules; the charge is 1,000 kilograms, and is about 1 meter high; care being taken that the granules shall not be so densely packed that the air will not be able to circulate. As soon as the pile, through dissolving, has sunk 0.24 meter, fresh quantities of copper are added; which is done two or three times a week. The consumption of sulphuric acid is 150 to 175 kilograms in twenty-four hours. The boxes are cleaned every eight to thirteen weeks. The granules are heated by the dissolving solution, which materially aids the oxidization. The temperature of the acid is important. If it is too high, silver is dissolved; if too low, the process is retarded. The solution from the dissolving-vessels should not be clear, which would show that the silver also is dissolved. Above the dissolving-vessels there is a sulphuric-acid reservoir. The raw sulphuric acid from the lead-chambers is conducted in the large reservoir, and superheated steam is led into the acid, whereby it is heated to 65° R., and at the same time diluted to 26° B. It is afterward changed to 32° B., by add-

ing the acid solution from the crystallization vessels. The sulphuric acid employed is 48° to 50° B. strong, and is manufactured at Altenau. Each dissolving-vessel communicates with the sulphuric-acid reservoir by means of a movable siphon. Every half hour the copper granules in the dissolving-vessel are washed with sulphuric acid from the reservoir by means of the siphon. The acid flows off rapidly; the oxide thereby formed on the surface of the granules are washed off by the next addition of acid with the argentiferous slime.

The copper-vitriol solution escaping from the dissolving-vessels flows through troughs into a large basin and from this into a system of open troughs, which again lead to another large basin. The solution, which at first is warm, partially evaporates while circulating in the troughs, and most of the copper-vitriol crystallizes upon the sides and bottom. The crystals with the argentiferous slimes adhering to them are removed and placed upon boards as soon as the troughs become filled.

The mother-solution running off is collected in a basin at the end of the system, and is again used for dissolving the copper-granules, as it is very acid. For this purpose it is forced up into the sulphuric-acid reservoir by means of a Giffard injector.

The raw crystals are dissolved in pans. The pans are of lead, 3.12 by 3.51 meters wide and 0.61 meter deep. They are heated by means of a Fairbairn smoke-consuming fire-place. Bituminous coal serves as fuel. Pure water is only partially used for dissolving the raw vitriol, the mother-liquid from the latter crystallization being principally employed. The pans are filled 0.25 meter high with mother-liquid, 0.10 meter high with water, and heated for 13 hours, whereby the fluid must reach a temperature of 75° or 80° R. Raw crystals are then placed within the pans until the solution reaches 28° B. It takes about 10 per cent. vitriol to produce this effect. A small amount of copper-granules are placed upon the bottom of the pan; about 1½ pounds of finely-pulverized copper and ¼ pound salt is strewn over the surface of the solution in order to precipitate any silver which may have been dissolved by the sulphuric acid or nitric acid which may have been contained in the unrefined sulphuric acid.

262. The solution is then allowed to stand for eleven hours without further heating, after which it is drawn off into crystallizing-tanks by means of a siphon. Since 1869 it has been filtered through granulated lead, and since 1870 also through granulated copper, in order to free it from any floating argentiferous slime, and also to precipitate the last traces of silver. As soon as the granulated lead and copper contain about 1 per cent. silver, the filters are renewed. It takes about one and a half months before the granules become this rich in silver. From 3 to 4 per cent. more silver is obtained by the employment of these filters than before they came into use. The loss ot silver in this process has been by this improvement reduced to 2 per cent.

The crystallizing-tanks are made of wood, lined on the inside with

sheet-lead. They are 3 meters long, 1.37 meters wide, and 1.10 meters deep, and have a capacity of 4 cubic meters, which corresponds to that of an evaporating-pan. From 120 to 150 lead strips are hung in each crystallizing-tank, upon which the crystals form. The first crystals generally form after about two days. In order to produce large crystals, the strips, which are already covered with crystals, are hung in the solution several times. Small crystals are always formed on the bottom of the tanks, but as they are always impure they are put back into the raw solution.

263. After the close of the crystallization process, the crystals are removed from off the lead strips and then placed upon an inclined table, where they drain off; they are then packed and ready for market. The remaining mother-liquid is then tapped off into a basin, from which it is forced up into the evaporating-pans by a Giffard injection, and used again for dissolving the raw vitriol. The copper-vitriol of Altenau is distinguished for its purity, as may be perceived by the following analysis:

	Per cent.
Iron	0.0107
Antimony	0.0123
Arsenic	0.0064
Zinc	Trace.
Nickel	Trace.
Silver	0.0006
	0.0300

The remaining argentiferous slime from the vitriol solution, after it has been drawn off into the evaporating-pans, is conducted to special boxes and well washed. The wash-water goes with the mother-liquids into the evaporating-pans. The following is an analysis of the argentiferous slime:

	Per cent.
Silver	3.100
Gold	0.004
Copper, (partly as $CuO\ SO_3 + 5\ Fbo.$)	7.150
Lead, (50.44 per cent. $Pbo\ SO_3$)	34.460
Antimony, (17.00 per cent. $Sb\ O_3$)	14.330
Arsenic	3.150
Sulphuric acid	16.670

264. The argentiferous slime while still moist is mixed with equal weight of litharge, formed into balls, dried and then subjected to a reducing-smelting in a litharge-reduction blast-furnace, with a flux of slag from ore and matte smelting. The resulting products are silver-lead, slag, rich in lead, and a matter rich in silver.

265. The silver-lead containing 1.50 per cent. to 1.90 per cent. = 437 oz. to 554 oz. silver, is cupelled. The resulting silver, however,

contains more copper than that from the lead-smelting. It is sent to Lautenthal for refining. The litharge is again used for mixing with the argentiferous slimes. The slag, containing 17 to 20 per cent. lead and 0.004 to 0.010 per cent. = 6 oz. 3 dwt. 7.68 gr. to 2 oz. 18 dwt. 4.8 gr. silver, is added to the lead-matte smelting-charge.

The matte rich in silver is formed, as the argentiferous slimes contain much copper; a part of the sulphuric acid, which it also contains, is reduced to sulphur and this combines with the copper, the result being a matte. It contains about 0.37 to 0.70 per cent. = 107 oz. 17 dwt. to 204 oz. 2 dwt. silver, 12 per cent. lead, 36 per cent. copper, and much antimony and arsenic. The formation of the product is not wished. For its further manipulation it is smelted with metallic iron, and the resulting products are silver-lead, containing about 1.13 per cent. = 328 oz. 17 dwt. silver, slag carrying 5 to 6 per cent. lead, and 0.003 per cent. = 17 dwt. 11.52 gr. per ton, and copper-matte with 38 per cent. copper, 0.3 per cent. silver, (87 oz. 8 dwt. 14 gr. per ton,) and 12 per cent. lead. The silver-lead is cupelled, the slag is used as a flux by the reduction of the argentiferous slimes, and the copper-matte collected until there is a sufficient quantity for its further treatment.

266. The annual production of copper-vitriol at Altenau is 450,000 kilograms.

267. ANDREASBERG.—Foreign silver-ores (Mexican) are the principal subjects of the Andreasberg metallurgical processes, as the silver and lead ores from the neighboring mines, and the old slags, containing small quantities of lead and silver, form but a small proportion of the material treated. The ores have a very varied composition and are mostly of a rebellious nature. The local ores are galena, with small quantities of silver mineral, copper and iron pyrites, blende tetrahedrite and bournonite, calcite, quartz, and argillaceous slate. The ores were formerly roasted in free heaps, but are now roasted in reverberatory furnaces which are connected with a system of condensation-chambers.

268. The smelting processes are divided into two classes: the first is for the ores which contain gold, the second is for ores which are free from gold. The composition of the charge is almost constantly changed, which is owing to the varying nature of the ores. The gangue, as a rule, is very difficult to fuse, and demands a large amount of flux. For this purpose slag from the ore-smelting is added. That portion is taken which is the richest in lead, silver, and gold. This slag has the following composition:*

Iron protoxide	13.7	24.7
Silicic acid	42.5	40.9
Alumina	19.5	15.3
Lime	12.6	8.8
Magnesia	7.1	6.6

* The data for Andreasberg are mostly from Dr. Wedding's communication in the *Preussische Zeitschrift.*

Copper protoxides	....	0.27
Lead-oxide	1.2	1.25
Silver	0.0025	0.003
	96.6025	97.823

It has been observed that a very small proportion of the gold in comparison to the silver enters the slag and matte. The charge for the first and second classes of ores, respectively, averages—

	1. Kilograms.	2. Kilograms.
Ore	100	100
Lead-flux	75	50
Slag from ore-smelting	287	211
Slag from the Lower Harz	20	48
Roasted lead-matte	29	31
1 kilogram coke carries	7.4	7.2
The round furnace smelts in twenty-four hours	6,600	6,650

The Rachette furnace is sometimes used for ore-smelting. The quantity of lead-flux is dependent upon the percentage of silver in the ore. In this connection the following rule is observed:

Lead-flux is added to the charge, in which the ore contains from 0.2 per cent.=58.3 oz. to 0.5 per cent.=145.8 oz. silver; silver-lead produced contains 0.5 per cent.=145.8 oz. silver; from 0.5 per cent.=145.8 oz. to 1 per cent.=291 oz. silver, silver-lead produced contains 1 per cent.= 291 oz. silver; from 0.5 per cent.=145.8 oz. to 1 per cent.=291 oz. silver, silver-lead produced contains from 1 per cent.=291 oz. to 2 per cent.= 583 oz. silver.

It is here apparent that the principle always kept in view is, the greater the quantity of lead in proportion to the silver put in the charge the less silver is slagged or absorbed by the intermediate products; but the lead loses through volatilization, &c., and the consumption of fuel in smelting and desilverizing the silver-lead is increased.

269. The amount of gold contained in the silver extracted directly from the Mexican ore, and the by-products in treating the same, is as follows: Silver extracted directly from the ore contains 0.887 per cent. = 259 oz. 15 dwt. 8 gr., gold; silver extracted from lead-matte contains 0.140 per cent. = 40 oz. 15 dwt. 4.8 gr. gold; silver produced from assaying slag from ore-smelting contains 0.277 per cent. = 80 oz. 14 dwt. 14.4 gr. gold; silver extracted from fumes contains 0.3 per cent. = 87 oz. 8 dwt. 14 gr. gold. The silver extracted from Andreasberg ores, and the by-products produced in treating the same, contain the gold in exactly an inverse ratio. This has been ascribed to the fact that the gold is very finely divided in the Andreasberg works when compared to the Mexican ores. The following are average assays: Silver extracted directly from ore contains 0.018 per cent. = 5 oz. 4 dwt. 20.6 gr. to 0.01 per cent. = 2 oz. 18 dwt. 4.8 gr. gold; silver extracted from lead-matte con-

tains 0.07 per cent. = 20 oz. 8 dwt. 4.8 gr. to 0.024 per cent. = 6 oz. 19 dwt. 22 gr. gold; silver produced from assaying slag from ore-smelting contains 0.1 per cent. = 29 oz. 2 dwt. gold. The slag produced by this operation is added to the charge for the ore-smelting. The silver-lead containing less than 0.5 per cent. = 145 oz. 16 dwt. silver, is sent to Lautenthal for desilverization. The silver-lead assaying over 0.5 per cent. silver is cupelled.

270. Silver-ores containing 10 per cent. = 2,916 oz. silver, or more, are added in quantities of 50 to 100 kilograms to about 5,000 kilograms silver-lead. The silver-lead is melted on the cupellation-hearth, the abstrich drawn off, and the rich silver-ore is thrown in the metallic bath by means of an iron spoon; whereupon the temperature is raised and kept at a high point for about one hour. At the end of this period the lead and lead-oxide will have absorbed the greater part of the silver. The slag formed by the gangue of the silver-ore and lead-oxide is drawn off by means of a piece of wood fastened at a right angle on an iron rod. The cupellation process is then conducted as usual.

271. The matte is roasted in shaft-furnaces, (kilns,) whereby the contents of sulphur are reduced from 23.4 per cent. to 5 per cent. These furnaces, and also the reverberatory roasting-furnaces, are connected with a condensation canal. The sides are built of slag-bricks, and are covered with iron plates; these are made air-tight by a coating of tar. The condensed fumes consist chiefly of arsenious and sulphurous acid, and contain 0.006 per cent. = 1 oz. 14 dwt. 16.22 gr. silver, and from 4.2 to 6.6 per cent. lead.

The charge for matte-smelting is as follows:

	Kilograms.
Roasted matte	100
Lead-flux	38
Slag	170

One kilogram coke carries 7.7 kilograms charge; 6,050 kilograms charge are smelted in a Rachette furnace in twenty-four hours.

The slag produced has the following composition:

	Per cent.
Iron protoxide	38.50
Silicic acid	30.15
Alumina	15.90
Lime	10.03
Magnesia	1.05
Copper protoxide	0.05
Lead oxide	3.55
Silver	0.003
	99.233

The slag from the old slag-dumps is smelted with the slag produced from day to day. The slag produced by this operation is, on account of

a lack of bases in the charge, comparatively rich in lead and silver, as the annexed analysis will show:

	Per cent.
Silicic acid	47.75
Iron protoxide	18.90
Alumina	21.20
Lime	6.00
Magnesia	2.90
Lead oxide	2.25
Silver	0.001
Arsenic and antimony	Trace.
Total	99.001

There are produced from the old slag 144,338 kilograms silver-lead, assaying 0.056 per cent.=16 oz. 6 dwt. 13.9 gr. silver, and 134,600 kilograms matte.

272. For 1871 the works at Andreasberg treated 518,000 kilograms ore; 137,000 kilograms of which was from the mines near that place.

273. LAUTENTHAL.—The ores treated at Lautenthal have the same general composition as the Clausthal ores. The smelting processes are conducted on the same principle as that which has been described when treating of Clausthal; a modification, however, is caused in the ore-smelting by a larger percentage of silica and zinc contained in the ore; an increased amount of basic copper-slag and matte is therefore added to the ore-charge. As the other operations have already been spoken of, it will suffice to remark that the ore-smelting is conducted entirely in Rachette furnaces with twelve tuyeres. The lead-matte has been roasted, since the fall of 1873, in shaft-furnaces. The fumes are utilized in the sulphuric-acid manufactory which was completed in the same year. The black copper is sent to Altenau for further treatment.

274. The silver-lead produced at all the smelting-works is desilverized at Lautenthal, with the exception of the rich silver-lead and that produced by smelting the old slags, which contain a large amount of copper, (Andreasberg,) and the silver-lead produced by the matte-smelting at Altenau and Clausthal, which are either too rich, (Andreasberg,) or contain so much copper that they are rendered unsuitable for the zinc-desilverization process, and are therefore cupelled without undergoing any concentration.

275. Pattinson's process, which was introduced at Lautenthal in 1864, was superseded in 1868 by desilverization by means of zinc. This was materially improved in 1869 by the introduction of steam (Cordurié's system) as an oxidizing and poling agent.

276. The silver-lead produced at the different works in the Upper Harz was formerly so pure that it could be desilverized by the crystallization process after having been melted in an iron kettle and poled. Its composition has not materially changed since that process was practiced.

Although it contains a large number of foreign substances, the quantity is so small as not to make it an impure article, as the analysis by Herrn Hampe, of Clausthal, will show:

Silver-lead from—

	Lautenthal.	Clausthal.	Altenau.
Lead	98.964	98.929	98.837
Copper	0.283	0.186	0.239
Antimony	0.574	0.720	0.768
Arsenia	0.007	0.006	0.0009
Bismuth	0.008	0.004	0.003
Silver	0.143	0.141	0.140
Iron	0.008	0.006	0.003
Zinc	0.002	0.002	0.002
Nickel	0.006	0.002	0.002
Cobalt	0.0003	0.0001	0.0001
Cadmium	Traces	Traces	Traces.
Total	99.9953	99.9961	99.9950

Although the silver-lead from each work is desilverized separately, they are all treated in the same manner. The process, as now conducted, may be regarded as giving general satisfaction, with the exception of the present method of extracting the silver from the rich oxide. Should the advantages of the method lately introduced at Tarnowitz be confirmed by a sufficiently long trial, it will be adopted at Lautenthal.

277. *The desilverization of silver-lead by means of zinc.*—Silver-lead is treated in fourteen Pattinson kettles 1.665 meters in diameter, and 0.75 meter deep. Each kettle is provided with a fire-place and separate chimney 8 meters high. Every three kettles form a battery. The two outside kettles are used for smelting and desilverizing the silver-lead, and the middle kettle is used for liquating the zinc-scum and desilverizing the lead therefrom. One kettle is employed to oxidize the zinc in the rich zinc-dust (*zinckstaub*) and in the fourteenth the abstrich is fused and poled. This kettle lasts but a short time, as the iron is attacked by the antimony, &c. The steam is generated in an iron boiler, (a second boiler being held in reserve), and, before entering the desilverization-kettles, passes through a steam-heating oven. A sheet-iron pipe, about 0.25 meter in diameter, runs from the condensation-chambers through the building about 2.2 meters above the floor; from this seven iron joints (one to every two kettles) are projected at a right angle to the main pipe; each joint serves to connect the main pipe with the iron hood which is placed on the kettles while the steam is being conducted in the molten metal.

278. *Melting the charge and removing the abzug.*—The silver-lead contains 0.13 to 0.14 per cent.=37 oz. 16 dwt. 19 gr. to 40 oz. 15 dwt. 4.8 gr. silver. The charge is 12,500 kilograms, which is melted in seven hours. If the fire is carefully regulated the skimmings (*abzug-schlicker*) composed partly of the copper, iron, &c., contained in the silver-lead, lie on the top of the metallic bath, forming a dark-colored crust from 2 to 4 centimeters thick. This is removed, and after having been liquated, is smelted with unroasted matte, (*vide* abzug-smelting.)

279. *Extraction of gold and copper.*—First addition of zinc.—After the abzug has been removed, 22.5 kilograms zinc is added to the silver-lead and the fire increased. The zinc melts in about half an hour, when the metallic bath is agitated for fifteen minutes with an iron disk 35 centimeters in diameter, which is perforated with round holes 2 centimeters in diameter. The fire is now lowered, and in order that the bath may not cool from the bottom or the side, the fire is only covered with ashes and the draught turned off. The metallic bath is now allowed to remain quiet about three hours. At the end of this time a blue and violet crust, termed *kupferschaum*, (copper-scum,) 4 to 6 centimeters thick, is formed, in which the gold and copper contained in the silver-lead are concentrated. The percentage of silver in the copper-scum is the same as in the original silver-lead. The silver produced from this contains about 0.12 to 0.2 per cent. = 34 oz. 18 dwt. to 58 oz. 6 dwt. gold. The copper-dross weighs about 500 kilograms. It is removed from the kettle with iron ladles about 20 centimeters in diameter, perforated with holes 1 centimeter in diameter. It is cast in molds and set aside until a large quantity has accumulated, when it is treated in the same manner as the zinc-scum. The enriched auriferous lead and oxides are also cupelled independently of the silver-lead, &c., and produce silver in which all of the gold contained in the original silver-lead is concentrated. After the scum has been removed the crusts which may have formed on the side of the kettle are scraped loose with small iron spades; they are then ladled out and added to the copper-dross. An advantage of this process is that small quantities of gold are concentrated in a small portion of silver and are extracted, which otherwise might be lost.

280. There are two theories advocated in regard to the crystalline copper-zinc and silver-zinc alloy separating from the zinc-lead alloy and rising to the surface of the metallic bath. According to one, it is in consequence of the difference in their respective specific gravities. The other theory is that it is owing to the difference in the congealing temperature of the two alloys. Herr E. Koch, of Clausthal, attempted to make a separation of the two alloys by throwing water on the surface of the molten liquid, but was unsuccessful. He then placed a U-shaped hollow iron tube in the molten alloy, cooled by means of water, and kept it there during the process, but the mass that congealed on the iron permitted no deduction favorable to his conclusion, as the lead-zinc alloy was solidified in about the same proportion as the silver-zinc alloy. He concluded, therefore, that the theory of the specific gravity was false, and that of the congealing temperature was the correct one. To say the least, his conclusion was erroneous; for the advocates of the first-mentioned theory are aware that a sudden cooling does not facilitate the separation; on the contrary, it is the slow and gradual sinking of the temperature that enables the alloy whose specific gravity is lighter to ascend. I would take still another step. It is more than probable that the separation is not owing to either one of the theories advanced,

but to both. When the zinc has been well mixed with the molten liquid, we have seen that the fire is only covered with ashes, so that the bottom and side are kept warm, and the metallic bath is cooled only from above. Zinc having a greater affinity for silver than lead for silver, displaces it and forms new alloys; the alloy of silver-zinc, having a smaller specific gravity than the lead-zinc alloy, ascends, and, coming in contact with the *very slightly* cooled metal, is solidified first, in virtue of a higher congealing temperature. Its tendency is then to float on the surface, but a small portion settles on the side of the kettle if that has become cooled.

281. *Extraction of silver.*—Second addition of zinc.—The fire is raised and a second charge of 90 to 95 kilograms zinc is added. One hour is consumed in melting this; at the end of that time the metallic liquid is well stirred for one-quarter to one-half an hour. The fire is then covered with ashes, and the bath is allowed to stand three to three and a half hours undisturbed. The iridescent crust which forms is 3 to 5 centimeters thick. It is termed *zinkschaum*, (zinc-scum.) The crust is removed with iron ladles and thrown into the next (middle) kettle. The crust is now removed from the side of the kettle by scraping with an iron spade, reheating the bath and allowing it to cool, whereby the silver-zinc alloy rises to the surface, and is ladled into the middle kettle. The lead now contains about 0.005 per cent. = 1 oz. 9 dwt. 3.8 gr. silver.

Experiments were made in the summer of 1873 to hasten and facilitate the formation of the silver-zinc alloy by conducting steam into the bath, but the formation of a large quantity of oxides was more than an offset to any advantages this might have shown. It was also attempted to effect a saving in zinc, by substituting the silver-zinc alloy, obtained from the third addition of zinc to a previous charge, for a portion of the 95 kilograms zinc added above. But it was found not to be an economical method, as the amount of silver extracted thereby was smaller than in the usual method, leaving more silver in the remaining lead, and necessitating an increased third addition of zinc.

282. Third addition of zinc.—The temperature is raised, and 53 kilograms of zinc is added to the remaining molten liquid. The manipulations are conducted exactly as with the second addition of zinc, with the exception of a longer scraping of the kettle-side. The temperature is also raised and lowered three times to insure a complete removal of the silver-zinc alloy.

283. The alloy is ladled into the adjoining kettle, which contains the alloy from the preceding operation. The total amount of zinc-scum produced is 3,300 kilograms. If the remaining lead assays over 0.0006 per cent. = 3 dwt. 11.9 gr. in silver, about 7.5 kilograms zinc are added and the last operation repeated. Should it not, which is generally the case, it is refined by means of superheated steam.

284. *Oxidizing zinc and antimony.*—By this operation zinc (0.5 per

cent.) is first removed, it being one of the metals oxidizable, when in a heated condition, by the oxygen of the steam.

285. Antimony, having a greater affinity for lead than for silver, remains, and is also to be removed; but as it does not decompose steam to a great extent, even when at a high heat, it must be eliminated by a separate operation. For this purpose steam is again conducted into the bath, and acts as an agitator; the antimony is oxidized by the oxygen of the air. A bent iron pipe, about 3.5 centimeters in diameter, extending to the bottom of the kettle, is fastened to the mason-work on which the kettle rests. This is used to conduct the steam into the molten liquid. A sheet-iron hood is next fastened and luted with damp clay to the kettle. This is about 1 millimeter high; has the same diameter as the kettle, and connects with the large pipe leading to the condensation-chambers. It has three small doors 10 centimeters square. The molten liquid is now heated to a little below cherry-red heat; and superheated steam is conducted into the bath under a pressure of two atmospheres; as the air is excluded, the temperature remains higher, the steam is decomposed, and the zinc is almost entirely oxidized in one and one-half hours. The oxides first formed are mixed with the liquid lead, but as the operation progresses they become "dry" and yellow, which is an indication that all of the zinc, together with a small quantity of lead, has been oxidized.

286. The lead is now tested for zinc. This is done by taking out a small ladleful and scraping the surface while hot with a piece of wood. The lead is free from zinc if the peculiar silky appearance is absent, which is caused by zinc. The hood is lifted up and the poor oxides are removed. After the hood has again been fastened on the kettle, and the three doors opened, the metallic liquid is heated to a cherry-red heat, and superheated steam conducted into the bath for one and one-half to two hours. The completion of this operation is known by taking out a small ladleful of lead and allowing it to cool. The absence of antimony is shown by the non-appearance of a small crystalline spot on the surface of the solidified lead. The abstrich is removed and steam conducted in the bath for three to six minutes, whereby a small qunatity of red litharge forms, which is an additional proof that the lead is free from impurities. The lead is then allowed to cool. Five hours are consumed in casting the "refined Harz lead" into molds; about 7,500 kilograms of lead are produced from each charge of 12,500 kilograms.

287. It has happened that crusts containing silver have adhered to the kettle, and have been resmelted in the high temperature just employed, and mixed with the desilverized lead. Therefore the refined lead is always assayed before casting, and if it contains more than 0.0006 per cent. silver, it is cast in molds, set aside, and added in small quantities to other charges before the third addition of zinc.

288. The regulation of the temperature is of great importance in both

these operations. If it is too low the oxidizing period is lengthened and there is a greater amount of lead oxidized. Care is taken at the same time, that the temperature shall not be too high, as the kettle would soon be destroyed.

289. *Liquation of the zinc-scum.*—The middle kettle is filled about three-quarters full with the zinc-scum from the kettle on either side. The fire is raised gradually, and the unmelted crust (*zinkstaub*) is removed. The fire is now lowered and the crust thereby formed, (*zinkstaub*,) zinc-dust, is removed and added to the unmelted crust. The fire is again raised and lowered twice, the crust formed being drawn off each time; the total amount of *zinkstaub* produced is 2,500 kilograms. From 10 to 20 kilograms zinc is now added to the lead and the same operation is repeated as by the third addition of zinc. The lead remaining in the kettle contains, besides zinc, a small amount of antimony. The presence of the latter is owing to a small quantity of the silver-lead taken over with the zinc-scum. The zinc and antimony are removed as in the preceding operation; the length of time for oxidizing the antimony is, however, shorter; one to one and a half hours being sufficient. The lead produced is termed "refined Harz lead."

290. *Dezinckifying the zinc-dust.*—This operation is performed in the end kettle, and as a high temperature is maintained the kettle is sooner destroyed than the others. If the zinc-dust which is to be dezinckified is too "dry," it contains only a very small quantity of lead. The bottom of the kettle not being covered with a liquid is soon attacked, and is liable to crack. About 5,000 kilograms zinc-dust are charged, the steam-conductor placed in position, and the hood fastened and luted to the kettle. This hood is 1.4 meters high, and is provided with three small doors, which are kept closed during the operation.

The temperature of the metallic bath is now raised to a bright cherry-red heat, and superheated steam, under a pressure of one and a half atmospheres, is conducted into the molten liquid for four to six hours. The end of the process is known by the dryness of the oxides and the formation of pure litharge. Before the hood is removed steam is allowed to enter above the surface of the bath for four to five minutes; for this purpose an extra small steam-pipe is used. The reason for this is, that the alloys just treated contain so much zinc (4 to 7 per cent.) that a large proportion of the steam is decomposed and leaves hot gases charged with hydrogen in the hood. Were these not first driven out with free steam, the hot oxyhydrogen gas would explode upon coming in contact with the air and wreck the condensation-chambers; this has several times occurred. The oxides, weighing 2,000 kilograms, are now removed; care being taken that they are not drained too dry, as this would cause a greater silver loss in the cupellation process by volatilization, and prevent a complete absorption of the silver by the lead. The enriched silver-lead remaining in the kettle weighs 3,000 kilograms.

The oxides contain about 60 per cent. lead-oxide and 40 per cent. zinc-oxide.

291. *Cupellation.*—From 5,000 to 7,500 kilograms of the enriched silver-lead, with 2 per cent. = 583 oz. silver, are laid on the cupellation-hearth, the hood put in position, and the charge fused. When the temperature approaches a bright, yellowish-red heat, from 400 to 500 kilograms of the rich oxides containing 1.2 per cent. = 347 oz. 6 dwt. silver, are thrown on the liquid silver-lead. A brisk fire is now made, the blast turned on, and the cooling caused by the addition of the oxides is soon overcome, and the mass fused. When the zinc-oxides have become desilverized, which occurs in about fifteen minutes in the high heat employed, the zinc-oxide is drawn off by means of a piece of wood on an iron pole; care is taken to have the metallic bath covered with a thin coating of the oxide, as otherwise, litharge would form, which is not now desired. The temperature is then raised, the blast turned off, and the preceding operation is repeated until the rich oxides, (2,000 to 2,750 kilograms,) have been charged and the desilverized oxides drawn off. The cupellation process now commences and is conducted as usual. The litharge formed, however, is impure, and is therefore reduced together with the slag formed by the oxides of zinc and lead and metallic lead, containing 0.17 per cent. = 49 oz. 10 dwt. 4 gr. silver. The resulting silver-lead is again desilverized. After the silver has brightened, hot water is thrown on it; an iron cross is then set in the silver, which is further cooled with cold water. The silver is $\frac{900}{1000}$ fine. If the temperature is carefully conducted, 6,000 kilograms silver-lead and 2,000 kilograms rich oxides are cupelled in twenty to twenty-four hours.

292. *Liquation of skimmings, (abzug.)* When a sufficiently large quantity of skimmings have accumulated, 10,000 to 15,000 kilograms, they are liquated; for this purpose one kettle is always used. From 1,000 to 2,000 kilograms of skimmings are thrown in the kettle and the temperature is gradually raised to a dark cherry-red heat; the lead is liquated and the real skimmings pushed together and removed. The rest of the skimmings are then added to the molten liquid and liquated in quantities of 500 to 1,000 kilograms at a time. In about fifteen to twenty hours the kettle will be full of silver-lead, which is ladled into the adjoining kettle, and is desilverized with three additions of zinc. It is necessary to perform the desilverization in another kettle than that in which the skimmings have been liquated, for the reason that the kettle is strongly attacked by the alloys; metal containing silver, &c., adheres to the cavities in the iron kettle, and these would become disengaged and impurify the silver-lead in all the stages, but particularly in the last, of its subsequent treatment.

293. *Treatment of skimmings*—Formerly the skimmings were added to the matte-charge; this produced silver-lead containing so much copper that it was impossible to break it with zinc. The skimmings are now

smelted with *unroasted* lead-matte; the result being a silver-lead comparatively poor in copper, which is treated with zinc and matte, which is roasted and treated with the copper-matte. The charge is as follows: 100 kilograms skimmings; 100 kilograms unroasted lead-matte; 75 kilograms slag from ore-smelting; 75 kilograms slag from matte-smelting.

294. *Manufacture of yellow paint.*—The poor oxides, from dezinckifying the poor lead with steam, are passed through a sieve; the pieces of lead are set aside, and the finer portion is washed on two sleeping-tables, together with the condensed fumes from dezinckifying and softening the hard lead. The water which carries off the oxides runs through five old Pattinson pots, where the oxides are allowed to settle. The large pieces of lead and the lead obtained by washing the oxides and poor fumes are reduced, and produce an inferior grade of lead. The zinc and lead oxides are dried in an oven and form a yellow paint; an article much sought after. It is composed of about 60 per cent. zinc oxide and 40 per cent. lead oxide; its commercial value is 6 thaler—$4.26 gold—per 50 kilograms.

295.—

Time consumed in desilverizing 12,5?0 kilograms silver-lead.		Weight of products from charging of 12,500 kilograms silver-lead and 150 kilograms zinc.	
	Hours.		*Kilograms.*
Fusing the silver-lead	6		
Removing the skimming	$\frac{1}{4}$	Skimmings	500
Fusing 22 kilograms zinc	$\frac{1}{2}$		
Stirring	$\frac{1}{3}$		
Cooling	3		
Removing the copper-scum	$\frac{1}{4}$	Copper-scum	500
Stirring, scraping, removing scum	$\frac{1}{4}$		
Fusing 92 kilograms of zinc	1		
Stirring	$\frac{1}{3}$		
Cooling	3		
Removing zinc-scum	$\frac{1}{4}$	Zinc-scum	2,000
Stirring, scraping, removing scum	$\frac{1}{3}$		
Fusing 53 kilograms zinc	1		
Stirring	$\frac{1}{3}$		
Cooling	3		
Removing zinc-scum	$\frac{1}{4}$	Zinc-scum	1,800
Stirring, scraping, removing scum	$\frac{1}{2}$		
Dezinckifying poor lead with steam	2		
Removing poor oxides	$\frac{1}{4}$	Poor oxides	350
Softening with steam	2		
Removing abstrich	$\frac{1}{4}$	Antimonial dross	150
Blowing steam without hood	$\frac{1}{3}$		
Casting refined lead	5	Refined lead	7,500
	30.35		12,800
		Lead-dross	200
			13,000

The surplus weight of the products is due to the fact that several of them are produced in an oxidized condition. The shift is twelve hours, but the workmen are paid per cwt. refined lead produced. There are four workmen, one fireman, and an overseer in each shift; two workmen attend to two batteries of three kettles each. The loss in lead is 1.62 per cent.; the loss in silver (loss in assaying calculated) 0.628 per cent.; consumption of zinc, 1.4 per cent.

The Harz refined lead, produced from Lautenthal silver-lead, contains, according to Herrn Schollmeyer, in 1870, the following amount of impurities:

Cu	0. 001413
Sb	0. 005698
Fe	0. 002289
Zn	0. 000834
Ag	0. 00046
Bi	0. 005487
Ni	0. 00068
	0. 016861

296. The following results of the silver-lead treated at Lautenthal by this process, in 1869, were published by Messrs. Wedding and Bräuning: Charge, 1,102,650 kilograms silver-lead = 1,584.17 kilograms silver and 1,101,050 kilograms lead.

The productions were:

	Silver.	Lead.	Silver.	Lead.
	Kilograms.	*Kilograms.*	*Per cent.*	*Per cent.*
Silver, 1,762½ kilograms contained fine silver	1, 621¾		102. 372	
Refined Harz silver		940, 188		85. 389
Muldenblei, (second quality bad)		95, 587		8. 682
Antimonial lead		24, 475		2. 223
Non-argentiferous oxides		2, 762		0. 250
Commercial litharge 3,200 kilograms		2, 937		0. 267
Total	1, 621¾	1, 065, 949	102. 372	96. 811
Unroasted products 22,600 kilograms		19, 612		1. 781
Grand total	1, 621¾	1, 085, 561	102. 372	98. 592

The unworked products were carried over to the next year and then treated.

The cost of desilverizing 1,000 kilograms silver-lead has been calculated by the following gentlemen:

Upper Harz, according to Herr Illing: Cupellation, 5 thaler; zinc-desilverization, 6¾ thaler; lead loss, 1.43; silver loss = 0.628 per cent.; Pattinson's process, 10 thaler.

At Havre, according to M. Graner:

	Cost.	Lead loss.	1 Treated per month.	Men employed.
	Francs.	*Per cent.*	*Kilograms.*	
Zinc-desilverization	20–25	1	500, 000	23
Pattinson's process	55	4–6	250, 000	50–52

297. The principal manipulations have been described, and the others may be seen by referring to the accompanying genealogical tree of this process. It will at first appear as though it were a very complicated process, but it must be remembered that the chart illustrates how even

the smallest product is treated, and that the greater proportion (85 per cent.) of the lead is extracted in a few simple manipulations.

298. This process, with the exception of the imbibation of the rich oxides, is undoubtedly the most advantageous for works where large quantities of silver-lead are treated. A pure silver-lead is not necessary for a successful operation; it is only when it is rich in copper and antimony that it needs a softening; but so do the other concentration processes. The loss in silver and lead is smaller than when the desilverization is conducted according to Pattinson's process, or when the zinc and antimony are eliminated from the poor lead in a reverberatory furnace. Fewer and less skillful workmen are required, and smaller quantities of coal are consumed, than with Pattinson's process. By the data given above it will be seen that with a few kettles a large quantity of silver-lead can be treated in a short time with but very small quantities of intermediate products, and producing a remarkably large percentage of commercial lead of a superior quality.

299. THE LOWER HARZ.—The display made by the smelting-works of the Lower Harz was not so large or so complete as that made by the works situated in the Upper Harz; but the specimens exhibited were exceedingly interesting.

The Oker Saiger Hütte exhibited statistical charts, pyritous ores from the Rammelsberg mine; from a worked-out part of (gob) the same mine large and good crystals of copper and iron vitriol, which resembled artificially-produced crystals; also cement, copper, and mine-water, containing salts of copper and iron in solution; sulphuric acid; selenium-slime from the fore-chamber of the sulphuric-acid manufactory; natron-sulphate, produced in the manufacture of iron-vitriol, from the refining of sulphuric acid, copper-matte, black and refined copper.

The Julius Hütte exhibited sulphur, zinc-vitriol, silver-lead, litharge, bismuth-litharge, and auriferous silver.

300. *Oker.*—The smelting processes at the Oker, Julius, and Sophien Hütte are based on the pyritous ores extracted from the Rammelsberg mine. The ores are divided into three classes. The first are copper-ores, and are composed chiefly of iron pyrites, intimately mixed with blende, copper, and arsenical pyrites. The second are the copper-lead ores, and composed chiefly of iron and copper pyrites, galena, and blende; they assay 3.5 to 5 per cent. lead, 2.8 to 5.5 per cent. copper, and 0.01 to 0.015 per cent. = 2 oz. 18 dwt. 4.8 gr. silver and a small amount of gold. The third class, or lead-ores, have the general composition of the copper-lead ores, but their copper contents are much smaller, and they assay from 4 to 10 per cent. in lead.

301. All the ores from the Rammelsberg mine were formerly roasted in free heaps, but since 1840 have been roasted in shaft-furnaces at Oker. The sulphuric-acid fumes are utilized in the manufacture of sulphuric acid. The copper and the copper-lead ores poorest in lead are reduced at that place, but the lead-ores are sent, after the first roasting, to the

Herzog, Julius Hütte, and Frau Sophien Hütte, and the copper-lead ores not worked at Oker are sent to the Frau Sophien Hütte for reduction. The rich copper and copper-lead ores are roasted in small shaft-furnaces 1.99 meters high, 1.26 meters wide at the top, and 0.63 meter wide at the bottom. The amount of sulphur in the ore is reduced in the first roasting to 12 per cent., producing 60 per cent. sulphuric acid of 50° B. The capacity of the furnace is 212 kilograms ore in twenty-four hours. The partly roasted ore is drawn from the furnace and the larger lumps roasted in shaft-furnaces 3.77 meters high, 1.88 meters wide, and 3.14 meters long; whereby the sulphur is eliminated to within 5 to 4 per cent., or a portion of the copper-lead ore, after having been once roasted, is sent to the Frau Sophien Hütte, where it is roasted twice in free heaps.

The poor copper and rich pyritous (iron) ores are roasted in the *kies-brennern*, (pyrites-roasting furnaces.) The bottom is formed by movable rectangular iron rods, by means of which the ore is discharged from the furnace. These furnaces, which were built in 1871, are 2.51 meters high, 6.28 meters long, and 1.26 meters wide. About 800 kilograms of the poor copper-ores are roasted in twenty-four hours to within 5 per cent. of sulphur, and from 1,000 to 1,100 kilograms of the pyritous ores are roasted in the same time to within 4 to 3 per cent. of sulphur.

The lead-ores and copper-matte are roasted in oblong shaft-furnaces 3.14 meters high, 3.14 meters wide, and 1.57 meters deep. About 42 per cent. sulphuric acid is produced from the roasting of lead-ores in kilns. After the first roasting they are sent to the Herzog Julius Hütte for further roasting and reduction.

A disadvantage of thus roasting the ore in shaft-furnaces is, that when the ore contains a large percentage of blende, a smaller amount of zinc-sulphate is formed than when the roasting is conducted in heaps; and consequently sulphuric acid must be added to the water when the zinc-vitriol is lixiviated, (*vide* roasting at the Herzog Julius Hütte,) in order that more zinc-sulphate may be formed, or the zinc-salts not dissolved in water will greatly disturb the smelting process.

302. *Copper-smelting.*—The roasted copper-ore was formerly smelted in low-hearth blast-furnaces (*Krummofen*) with one tuyere. They were 2.09 meters high; width in front, 0.42 meter; width behind, 0.63 meter, and 0.94 meter deep. The charge was composed of roasted ore, calcined and raw argillaceous slate, slag from the matte-smelting, and occasionally small quantities of slag from the ore-smelting. The products were *königskupfer*, (copper containing arsenic and antimony,) with 75 to 90 per cent. copper and 0.2 per cent.=58 oz. 6 dwt. silver; it was refined, granulated, and the silver extracted with dilute sulphuric acid. Raw matte, with 50 per cent. copper and 0.05 per cent.=14 oz. 11 dwt. 14 gr. silver, was roasted in heaps and smelted in the ore-smelting furnaces with argil-laceous slate. The copper from this operation was refined. The process of oxidation being carried too far, a small quantity of lead was added

to the copper and it was again refined. The copper-matte from the same smelting containing 60 per cent. copper, was roasted in heaps from five to six times, and then smelted without any flux. The copper here produced was refined with the over-refined copper from the previous operation. The presence of a large amount of iron in the ore caused a very imperfect smelting process, and although numberless attempts were made, for the purpose of removing the many difficulties attending the reduction of the ores in shaft-furnaces, none met with material success.

303. The latest experiments* mentioned in that direction were made in a shaft-furnace 3.4 meters high; it had at first four tuyeres, but, as these were found to be too many, this number was reduced to two. An acid flux of slag from the ore-smelting in the Rachette furnace at Lautenthal, was substituted for the basic slag formerly used, but the reduction of iron and the formation of salamanders were increased, instead of being diminished, and the furnace had to be blown out after a three-days' campaign. It was hereby observed that the reduction of iron increased in proportion to the width of the smelting-zone. Other experiments in this furnace, with differently-constituted charges, led to like results. The use of Mansfeld copper-slag from the ore-smelting, as a flux in shaft-furnaces with one tuyere, was also unsuccessful. It was expected to extract the copper it contained, (0.6 per cent.,) but this was not possible, as a slag was produced with a still greater amount of copper. The process, however, would have been more advantageous than the one then in vogue, had not the large amount of this slag, (60 to 70 per cent.,) used as a flux, caused a correspondingly large consumption of fuel.

It was concluded in 1870 to abandon the method of reducing the ores in shaft-furnaces, and adopt the process, now extensively employed in England, of roasting the partly-desulphurized ores with salt, dissolving the copper, silver, and gold, and a subsequent precipitation of the same.

304. The works for this process were accordingly commenced in 1871, completed in 1872, and the process put in operation in 1873. The plant for this process is at present limited, but is arranged so as to admit of being extensively enlarged. It consists in a mill for crushing the roasted ore from the sulphuric-acid manufactory, a reverberatory roasting-furnace with a gas-generator attached, in which the ore is roasted with salt, and the necessary lixiviating and precipitating tubs and boxes.

Herr Ulrich, superintendent of the Oker smelting-works, has proved by a series of experiments that ores with 10 to 12 per cent. copper and 8.26 to 9.26 per cent. sulphur are as suitable for this process as ores much poorer in copper. In England, 4 per cent. is considered the maximum amount of copper for ores to be treated by this process. The richer ores naturally require a longer roasting period. It was also shown by these experiments that 15 per cent. of salt was the proper quantity for ores with the above percentage of copper. The copper-ores

* These experiments are from Dr. Wedding's improvements in the government works *Preussische Zeitschrift.*

were first treated in 1873 at Oker according to this method. The period, therefore, in which this process has been in operation is so short that it scarcely is to be considered as perfect; for the daily experiences with a process newly introduced continually show where improvements can be made and where alterations are necessary.

305. The different manipulations may be classed as follows:

CHLORINATION PROCESS.—PRELIMINARY OPERATIONS.

1. Crushing the roasted ore from the sulphuric-acid manufactory.
2. Roasting the crushed ore in a reverberatory furnace with salt; a certain proportion between the copper and sulphur is desired. It is stated that for a successful operation the sulphur in the ore must not be more than 1.5 as much as the copper contents.

Copper extraction.—1. Lixiviating the chloridized ore with water, then with the solution from the first lixiviation of a preceding charge; these two solutions contain the greater part of, and the purest copper; also about 95 per cent. of the silver and a corresponding amount of gold. The silver is dissolved by means of the alkaline salts of chlorine, which always exist in the mass in larger or smaller quantities. The residue is finally treated with very dilute hydrochloric acid; the copper extracted by means of the acid solution is impure, and is used in the production of inferior grades of copper.

Each dissolving liquid seldom remains in contact with the ore more than one hour, care being taken that it is tapped off immediately upon its ceasing to dissolve fresh quantities of copper salts. The decopperized residue is removed, and the lixiviating-box prepared for a new charge.

Silver and copper precipitation.—1. The solution containing 95 per cent. of the silver and gold is treated, according to M. Claudet's patent, with iodide of potassium. This is too well. known to need a further description here.

2. The copper is precipitated by means of iron; steam is conducted into the dissolving-liquid, which greatly facilitates the precipitation.

Copper-smelting.—1. The copper extracted from the water solution is smelted with black copper, which is refined, and produces copper of a superior quality.

2. The copper from acid solution is smelted for matte; this produces copper of a poorer quality.

306. The manufacture of sulphuric acid and copper-vitriol is conducted here in the same manner as at Altenau, but on a much more extensive scale. Attempts were made to roast the powdered ore *(erzklein)* in a Hasenclever and Helbig furnace, but the unsatisfactory results which were obtained are ascribed to the unfavorable condition of the ore, which, having previously been exposed to a damp atmosphere, had partly undergone a chemical reaction in the formation of copper and iron vitriol. This is, therefore, no criterion of the inadequacy of this furnace, which has given very good results at other places.

307. Experiments, made in concentrating sulphuric acid with the view of economizing fuel, have shown that only where there is a large amount of heat generated, as in the shaft-furnaces, wherein the copper-ores are roasted, is it possible to concentrate the acid without appropriating heat, which is necessary for a good roasting of the ore. The attempt to concentrate the acid by a battery of cylindrical jars of lead and porcelain was also unsuccessful. The latest trials were made by conducting steam in lead pipes through the acid, the results of which the author has not been able to obtain.

308. The Oker smelting-works produced in 1872: 1,000,000 kilograms of copper-vitriol; 400 kilograms of argentiferous copper.

309. *The Herzog Julius Hütte.*—The copper-lead ores which have undergone one roasting in shaft-furnaces at Oker are sent to these works for reduction. They are roasted twice in heaps; the first roasting is conducted in the open air, the second under a roof. The heaps are about 2.25 meters high; length of sides at the bottom 9.5 meters, at the top 3 meters. The roasting-period is 18 to 22 weeks. The heap is covered with fine ore, which has been twice roasted. The sulphur, owing to an insufficient access of air, is only partially oxidized; another portion is sublimed, and is obtained by making deep round cavities in the top of the heap. The sulphur, upon coming in contact with the atmosphere, passes into a liquid state, is cooled, and precipitated on the sides of the round cavities. It is removed every morning.

The second roasting in heaps is conducted under a roof; upon the completion of the roasting, sulphuric acid is thrown over the heap, and the zinc-sulphate is washed to the bottom. The fine ore from the bottom is taken to the lixiviating-boxes.

310. *Manufacture of zinc-vitriol.*—The zinc-sulphate, which is formed during the first roasting, is partly washed to the bottom by being exposed to the weather, so that, when the roasting is finished and the top and larger pieces of ore removed, the fine ore and that in the bottom of the heap contain considerable zinc-sulphate; this is removed to large lixiviating-boxes, and, together with ore obtained from the second roasting in heaps, is treated as follows: The lixiviating-boxes are 2.6 meters long, 1.4 meters wide, 1 meter high. The water enters through a wooden trough over the top of the box. On one end of the box four spigots are placed; the lower is 0.2 meter from the bottom, the other three are situated, each, 0.1 meter higher than the preceding spigot. The ore is lixiviated with water, to which 10 per cent. of sulphuric acid has been added. The ore and liquid are well mixed by an energetic stirring with poles. After the mass has settled over night, the liquid is tapped off by means of the spigots in the end of the box. The same process is then repeated. The residue is dried and sent to the ore-smelting. The liquid is first conducted into a reservoir, where the impurities, mechanically held in solution, are allowed to settle; it is then conducted into a large leaden pan and heated, whereby iron sesquioxide is precipitated. Copper is

next precipitated by allowing the solution to flow into boxes, in which strips of zinc are suspended. The solution is then conducted back into the lead evaporating-pan, and kept at 60° to 80 °R. until the zinc-vitriol commences to foam, when it is tapped into wooden tubs, in which long thin pieces of wood are suspended. The first portion of zinc-vitriol that forms contains silver; the solution is therefore only allowed to remain for a certain time in the first crystallization-tub and is then conducted into a second, where a complete crystallization takes place. The zinc-vitriol from the second tub is dried in a muffle-furnace, and, although containing a small amount of impurities, is an article of commerce which finds a ready sale. The zinc-vitriol from the first crystallization-tub, containing a small amount of silver, is first calcined in a muffle-furnace, and then added to the charge for the ore-smelting in small portions. From 17 to 20 per cent. of the zinc contained in the ore is extracted by this process. This is not only an economical method of extracting zinc from poor pyritous ores, but the much-desired elimination of zinc from lead, copper, and silver ores is also effected. The plant necessary for this process is inexpensive, everything being constructed of wood, except the leaden evaporating-pan and muffle drying-furnace; the cost of labor is also very small. It is, however, necessary that the roasting be conducted in free heaps, in order that the formation of zinc-sulphate may be large; as this compels capital to remain idle for a long time, it is not often to be recommended.

311. The smelting of the lead-ore is conducted in hearth blast-furnaces with one tuyere. They are 4.39 meters high, 0.549 meter wide at back, 0.314 meter wide in front, and 1.2 meters deep. The charge is composed of 100 kilograms roasted and lixiviated ore, 27.7 kilograms copper-slag from Oker, 22.41 kilograms ore-slag from Lautenthal, 2.66 kilograms lead-flux, 33 kilograms coke, 2 kilograms charcoal. The campaign commences every Monday morning, and on account of the formation of salamanders, lasts only until the following Saturday, when the furnace is blown out.

312. The products are slag, silver-lead, matte, and a small amount of lead-speiss. The slag is broken with sledge-hammers, and the pieces containing ore, or silver-lead mechanically mixed, are picked out and added to the ore-charge, the rest discarded. The silver-lead is melted and poled in a Pattinson's kettle, the abzug is removed, and the lead is cast into molds. The silver-lead is then cupelled in a German cupellation-hearth. The charge is 10,000 kilograms, from which 6 kilograms of fine silver are produced. The abstrich is reduced, liquated, and antimonial lead produced. The rich litharge is added to the ore-charge; the poor litharge is either sold or reduced in a low shaft-furnace. The lead-matte, containing 2.75 per cent. lead and 3.9 per cent. copper, is subjected to three roastings in free heaps, and is then smelted with slag from Oker and slag from the ore-smelting at Lautenthal. The silver-lead produced is treated in the same manner as the silver-lead

from the ore-smelting and cupelled. The copper-matte is roasted three times in free heaps, and then smelted for black copper with 3 per cent. of slag from Oker and 3 per cent. of calcined argillaceous slate. The black copper is sent to Oker.

313. There are at present in operation at the Herzog Julius Hütte six smelting-furnaces, two cupellation-furnaces, and a zinc-vitriol establishment. It treated, in 1870, 5,321,000 kilograms of lead-ore.

314. GEWERSCHAFTLICH MANSFELDISCHEN HÜTTEN.—The Mansfeld Smelting Company was represented by products of copper-smelting, such as refined copper and copper worked up into various articles of commerce, silver extracted according to Ziervogel's method, and a model of a Pilz furnace with six tuyeres, newly erected at the *Krughütte*.

315. The round furnace (*vide* Fig. I) has entirely superseded the "spectacle" furnaces, (*i. e.*, having two reception basins in front,) and has also proved its immense superiority over the latter. The new furnace at the "Krughütte" was built according to the drawing, (Fig. I,) with the exceptions that a Langon's charging-hopper was substituted for the Parry's; and, as the high furnace worked too energetically in the reduction of iron, and produed a matte rich in iron and poor in copper, the newly-erected furnace only measured 7.22 millimeters from the sole to the top, 1.88 millimeters in diameter at tuyeres, and 2.20 millimeters at the top. By smelting with a small pressure of blast, an even and uniform working is effected. The matte and slag are separated more perfectly in the highly-heated crucible than in hearth-furnaces.

DIMENSIONS AND DESCRIPTION OF FIG. I.*

a. Furnace-shaft.

b. Slag-spout.

c. Tap-hole for matte, which runs through the spout *d* into the dividing-trough *e*, into the water-basin *f*, where it is granulated and prepared for the following operation—roasting.

g. Blast-pipe.

h. Gas-pipe leading to the canal, *l*.

k. Parry's hopper, 0.94 millimeter in diameter and 0.78 millimeter high. By lowering and raising the iron cone, *i. e.*, above and below the opening *xx*, the charge is directed toward the periphery or center of the shaft.

m. Lining, at the bottom 0.47 millimeter, middle 0.31 millimeter, top 0.26 millimeter thick.

n. Mantle at bottom 1.02 millimeters, top 0.68 millimeter thick, 6.43 millimeters high, and is supported by iron pillars *o*.

The blast-nozzles and matte tap-hole are cooled by iron boxes containing spiral-shaped wrought-iron tubes, through which the water circulates.

*The dimensions and drawing are taken from the "*Berg- und Hüttenmanische Zeitung,*" 1874, p. 115.

316. The ore treated is principally a copper-schist, occurring in beds in Zechstein. The beds have a maximum width of 63 centimeters, but only about 5.18 centimeters of this is sent to the works for reduction. The ore contains from 1.6 per cent. to 4 per cent. copper; the copper carries 0.56 to 0.15 per cent. = 43 oz. 13 dwt. to 163 oz. 15 dwt. 19 gr. silver. The important mining industry of Mansfeld had its commencement toward the close of the twelfth century, and since that time the mines have been worked uninterruptedly. At first the ore was smelted for black copper, and the latter desilverized by liquation, but the dearth of lead-ores was the cause of the adoption of the Augustin process in 1830. At first this process did not meet with good success, but, later on, gave better results.

317. *The Augustin silver-extraction.*—It has been long known that chloride of silver is soluble in a solution of chloride of sodium. It is spoken of by Karsten in his view of the process of amalgamation, and it was also formerly made use of in Freiberg in the chlorination roasting.

It was Augustin, however, who in the year 1843 first made use of it on a large scale at the Gottesbelohnung Hütte, near Mansfeld. The process consists in an oxidizing roasting, followed by a chloridizing roasting of the argentiferous substance; dissolving of the chloride of silver thereby formed in a chloride of sodium solution, and precipitation of the silver with metallic copper. This method is only capable of treating such substances as are free (or nearly so) from all ingredients that act disadvantageously to the process. When such substances are present the reactions take place but imperfectly, and the process is accompanied with a great loss of metal. This process therefore was better suited for argentiferous metallurgical products than for silver-ores, as the former is more apt to have the required composition. Experiments have been made at several places with this method and even adopted at some works, but with few exceptions it has been replaced by others.

318. The Augustin process was superseded by the "Ziervogal water lixiviation process" in 1848. This process is based upon the conversion of the sulphide of silver contained in an ore or metallurgical product into a sulphate, by means of roasting, dissolving the sulphate of silver in hot acidulated water, and precipitation of the dissolved silver with metallic copper. This is one of the most subtle processes known to the science of metallurgy, as regards the oxidizing roasting. The oxidation of the sulphate of silver is principally effected by the gaseous sulphurous acid, set free in the roasting temperature from the sulphate salts present. The salt most friendly disposed to assist this reaction is sulphate of copper, it being disposed to part with its sulphuric acid during the period in which the sulphate of silver is formed. The presence of protosulphide of iron is of advantage within certain limits, as it is converted into a basic salt of the sulphate of sesquioxide of iron, and as this salt parts with its sulphuric acid during an early stage of the roasting-process, the latter is decomposed, and the oxygen converts the sulphide

of copper into a sulphate, whereby the formation of copper-vitriol is forwarded and the length of the roasting-period is shortened. The rich copper-matte, (70 to 72 per cent. Cu,) poor in iron, (11 per cent. Fe,) of Mansfeld, is exactly suited to this method of treatment. Experiments were made in Schemnitz with argentiferous raw-matte, which was principally composed of protosulphide of iron. Only 73 per cent. of the silver contained in the matte was obtained, and 27 per cent. remained unextracted in the residue. If metallic copper is present in the matte, it acts disadvantageously in the extraction.

In England, black copper is granulated, calcined, crushed, and then roasted with copper and iron vitriol.

It is necessary that the substances to be treated by this process should be free from the following ingredients, viz: zinc, arsenic, and antimony, for they dispose the silver to volatilization; the sulphides of lead and antimony cause the roasting-charge to agglomerate. In a well-conducted roasting it is principally oxides (oxides of iron and copper) and sulphate of silver that are formed; some sulphide of copper is also produced. If the temperature becomes too high, (much higher than from 750° to 770° C.,) the sulphate of silver formed will be decomposed and metallic silver formed. It is clear from the above that the process, although the cheapest method of silver-extraction from copper ore or products, is seldom capable of being made use of, on account of its requiring very pure material, (so far as regards the points above mentioned,) as well as expert and experienced workmen.

319. Between 1864 and 1866, the manufacture of sulphuric acid and the use of Gerstenhöfer furnaces, for roasting the granulated and powdered copper-matte, were introduced; and since 1867 the following improvements have been made: Blast-furnace with six tuyeres and blast-kilns for the production of sulphuric acid, and a dispensation of the black-copper process by using rich desilverization residue, (entsilberungsmehle.)

320. The present reduction process is simple. It consists in a roasting of the ore, followed by a smelting for copper-matte; this is roasted in powder form, (Gerstenhöfer furnace,) and then is desilverized by the Ziervogel process; the copper residue is then smelted and refined. The production of these works for 1872 amounted to 22,900 kilograms silver, 5,500,000 kilograms copper, and about 4,550,000 kilograms sulphuric acid of 50° B. Six thousand men are employed in the mines, and 1,100 at the reduction-works.

321. UPPER SILESIA.—The following articles were exhibited from the Friedrich Hütte:

A twisted square rod of soft lead, and another rod of soft lead which had been hammered out to 12.4 times its original length.

Several products from the operations of zinc desilverization and smelt-

ing were exhibited, giving the visitor an interesting insight into their operations. They were:

Rich argentiferous zinc-dross, containing 0.4 per cent. silver = 116 oz. 12 dwt. per ton of 2,000 pounds, and dross from liquation carrying 68 to 70 per cent. lead and 1.5 to 2.5 per cent. silver=436 oz. 16 dwt. to 728 oz. 16 dwt. per ton of 2,000 pounds.

Fumes from the desilverization-works, containing 47 per cent. lead and 0.018 per cent. silver=7 oz., nearly; residue from ore-smelting in reverberatory furnaces, carrying 38 to 50 per cent. lead and 0.01 to 0.04 per cent. silver = 2 oz. 18 dwt. 4.80 gr. to 11 oz. 13 dwt. 4.80 gr.; fumes from the blast-furnaces, with 70 per cent. zinc oxide and 3 per cent. lead and cadmium oxide; other fumes from shaft-furnaces, with 80 per cent. Zn. O and 2 per cent. Pb. O; fumes from reverberatory furnace, with 50 per cent. Pb. and 0.009 per cent. Ag. = 2½ oz.; fumes from cupellation-furnace, with 62 per cent. Pb. and 0.015 per cent. Ag. = 5½ oz.; impure slag, assaying from 2.5 to 6 per cent. lead and 0.002 to 0.006 per cent. silver = 11 dwt. 15.84 gr. to 1 oz. 14 dwt. 23.52 gr.; trift-schlacke, (top slag,) with 0.25 to 1.0 per cent. lead.

322. Upper Silesia has not so great a variety of mineral treasures as Lower Silesia, but her ore-deposits are more extensive—in fact, it is the richest mineral district in Germany. Argentiferous galena, forming a continuous bed, in the "Muschelkalk," is principally found on or near the bordering limestone or dolomite. It also occurs in nodules, associated with cerusite, in the calamine beds. The ore is almost free from metallic impurities. It contains more or less blende, small amount of silica, 1 per cent. alumina, 2.3 per cent. carbonate of protoxide of iron, and considerable quantities of sulphate and carbonate of lead. It contains from 0.0734 to 0.0764 per cent. = 22 oz. silver.

323. The Tarnowitz Lead and Silver Smelting-Works were erected in 1786. The iron-reduction process was first practiced, using iron tap-cinder as the precipitation-medium, as the ores carried a large percentage of zinc-blende. This method was succeeded by smelting in what were pronounced to be Flintshire furnaces. About the year 1864 the production of ore increased to such an extent, that it was found necessary to erect larger furnaces. These are now the largest reverberatory furnaces in the world. They are built with eight working-doors, and hold a charge of 3,750 kilograms of ore. The new furnaces are of the following dimensions: Length of hearth, 5.07 meters; width, 2.772 meters. The fire-bridge is 1.883 meters long and 0.732 meters wide. The fire-grate is 2.51 meters long and 0.523 meter in width. The working-doors are 0.262 wide and 0.209 meter high. The flue is divided into four compartments, and is 1.36 meters wide by 0.392 meter high. The hearth consists of a layer of sand; then a layer of clay bricks, 0.157 meter thick; then a brasque-hearth, on the top of which is melted a layer of basic iron tap-cinder. The old furnace contained a charge of 2,000 kilograms ore. The consumption of fuel in the new furnaces is per 100 kilograms ore but little

more than half of the consumption for a like amount of ore in the smaller furnaces. As the workingmen are paid according to the amount of silver-lead produced, the wages remain the same.

324. There are three distinct smelting-operations, as the processes are conducted at present. The ore carrying about 73 per cent. of lead is treated in the large new furnaces, with what is known as the combined Carinthian and English processes. The time consumed in roasting is three to four hours; the entire manipulation lasts seven hours. The five new furnaces have a capacity of 8.450.000 kilograms ore a year; this is calculating thirteen charges per furnace a week and forty working weeks. The ore containing from 40 to 50 per cent. lead, and often carrying considerable zinc, is smelted in the old furnaces, according to the iron-reduction process in reverberatory furnaces. Iron-slag from the puddling-furnace has been found to act much better than metallic iron. The oxygen liberated when the iron unites with the sulphur acts powerfully oxydizing. The charge is composed of 1,500 kilograms galena-slimes, 500 kilograms cerusite, and 2,000 kilograms ore. From this there is produced from 15 to 24 per cent. silver-lead. This charge is first agglomerated, then iron-slag from the puddling-furnace is added; a large amount of zinc is volatilized as zinc oxides. It was attempted to dissolve zinc in raw lead-matte (as is successfully done in Freiberg) by an addition to the charge of 5 per cent. of the product; this, however, gave very poor results. The residue is smelted in shaft-furnaces, with 20 per cent. of iron-slags from the puddling-furnace, and 30 per cent. of poor slag from the same operation. The third smelting-process is that whereby the ore containing under 40 per cent. of lead is (since 1868) first agglomerated in a reverberatory roasting-furnace, (Fortshaufelungsofen.) Water, carbonic acid, and a small amount of sulphur are hereby driven off, and the ore is then prepared for smelting in shaft-furnaces, which follows. These were materially improved in 1868; they were widened toward the top and furnished with water-tuyeres. A campaign lasts about eight weeks. The ore and fuel are charged in alternate horizontal layers. The residue from smelting the rich ore, without the addition of iron, or substance containing this metal, forms the greater part of the charge. The charge is made in proportion to the above residue. This residue is composed of:

33. 18	per cent. lead oxide.
13. 27	per cent. lead sulphate
22. 86	per cent. zinc oxide.
8. 96	per cent. iron peroxide.
11. 19	per cent. lime.
3. 56	per cent. silicic acid.
1. 83	per cent. iron protosulphide.
4. 82	per cent. carbon.
0. 015	per cent. silver.
99. 685	

Composition of charge:

100 kilograms residue from slime smelting.
50 kilograms agglomerated slime.
20 kilograms rich litharge.
10 kilograms hearth, from cupellation-furnace.
3 kilograms iron.
55 kilograms slag from puddling-furnace.
5 kilograms limestone.
40 kilograms slag from same process, half of which contains lead and silver.

In consequence of the increased dimensions of reverberatory furnaces, and the attending increased production of residue as well as silver-lead, it was found necessary in 1871 to erect new free-standing and round shaft-furnaces with eight tuyeres and the siphon top of nu. Arents.

The following are the results of the smelting operations in the large furnaces in 1863, 1864, and 1865: *

Year.	Amount of silver and lead in ore.		Lead produced from the furnaces.	
			Kilograms.	Assaying.
1863	69.81 per cent. Pb	0.0764 per cent. Ag	2,549	0.137 per cent. silver.
1864	71.01 per cent. Pb	0.07341 per cent. Ag	3,050	0.116 per cent. silver.
1865	72.97 per cent. Pb	0.07461 per cent. Ag	3,192	0.113 per cent. silver.

Five thousand kilograms ore gave:

Year.	Residue.			Fumes containing—		
	Kilograms.	Lead.	Silver.	Kilograms.	Lead.	Silver.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1863	1,587.5	47.5	0.018	53	....	0.012
1864	1,032	45.3	0.0111	70	50	0.005
1865	796	38.8	0.0135	137.5	....	0.009

The loss was:

	Lead per cent.	Silver.
1863	3.22	0.0077
1864	2.96	0.0003
1865	1.65	0.00008

The production of the different metals contained in the charge was:

	Lead per cent.	Silver per cent.
1863	73.03	91.855
1864	82.43	96.392
1865	87.49	99.915

The balance remained in the intermediate products.

By the smelting of 100 kilograms ore, containing 72.97 per cent. lead

* *Vide* Percy Rammelsberg, *Metallurgildes Bleies* 1872.

and 0.074 silver, 46 kilograms bituminous coal was consumed. The product was 63.84 per cent. silver-lead, 15.92 per cent. residue, containing 39 per cent. lead, 2.75 per cent. fumes containing 50 per cent. lead, equal to a production of 87.49 per cent. lead and 99.9156 per cent. silver, giving a loss of 1.65 of lead, 0.00008 per cent. silver.

The lead from the several tappings assayed as follows:

	Quantity in kilograms.	Per cent. silver.
First tapping	440	0.1445
Second tapping	368.5	0.1210
Third tapping	261	0.1095
Fourth tapping	133	0.0995
Fifth tapping	106.5	0.1035
Total, (medium)	1,309	0.5780

325. M. Gruner made a calculation of the capacity of the principal furnaces using the English or Carinthian methods, or modification of both. In his estimation he takes three hundred working-days in the year, and ore containing 70 to 80 per cent. lead.

Carinthian furnace, 150 tons; 1 ton = 1,000 kilograms.

The furnace at Engis, 350 to 400 tons.

Bleyberg furnace with two fire-places, 1,200 tons.

English furnace at Snailbeach, 1,000 tons.

English furnace in Flintshire, 1,200 to 1,400 tons.

English furnace at Tarnowitz, 1,200 to 1,400 tons.

From a comparison made by Percy of the capacity of the same furnaces I take the following figures; the capacity of the Carinthian furnace is taken at the unit:

Furnace.	Lead assay of the ore.	Size of charge.	Amount of lead produced in the same time.
	Per cent		
Carinthian furnace	67.4	1	1
Spanish	77.7	4	6
Alport		5	7.5
Flintshire	75.80	6	113.6
Tarnowitz	73	6.10	16

The large production in the Flintshire furnace is owing to the principle there employed, viz, of shortening both the roasting and reaction periods. This is necessary in order to treat the immense amount of ore. The disadvantage accompanying such a process is the high temperature employed, causing volatilization of lead and silver, to condense which extensive chambers are employed. This is considered of less importance than the increased production, the saving of fuel, and general expenses.

326. *The zinc-desilverization process.*—Pattinson's crystallization pro-

cess was experimented on at these works in 1837, but was first introduced on a large scale in 1861. This gave way in 1869 to the zinc-desilverization process. Already, in 1842, Karsten* published that he had discovered that lead gives up its contents of silver to zinc in proportion as a melted mixture of lead and zinc is exposed to the conditions most favorable to a complete separation, which is slow cooling. He did not suggest, however, that this be applied to practical metallurgy; but one year after Mr. Parkes had taken out his patent (1850) for the desilverization of lead by means of zinc, Karsten made a number of experiments on a large scale, which did not lead to successful results. Karsten attributed the failure to the formation of dross and oxides attending the mixing of the zinc and silver-lead, which withdrew much metallic zinc. Percy more correctly ascribed it to the imperfect separation of zinc from lead.

327. The zinc-desilverization process was practically introduced here in 1869, and Pattinson's process discarded. The difficulties which were attendant upon the separation of the rich zinc-dross, (*zinkstaub*,) and which caused several small private works to re-adopt Pattinson's process, have been, at the Friedrichshütte, successfully surmounted. Steam (Cordurié's method) was employed to oxidize zinc, &c., and the method was similar also in other respects to the one employed at Lautenthal. Although the imbibition of rich oxides by the cupellation of the silver-lead is, in Lautenthal, preferable to Flach's method, it is, on account of the large quantity of abstract produced, containing much silver and zinc, and the high temperature employed, &c., an extremely undesirable process. In addition to this, the absence of copper and antimony from the lead caused such a large amount of lead to be oxidized by the separation of the zinc-silver alloy from the lead-silver alloy, (*i. e.*, rich oxides from zinc-dust,) by means of steam, that it was found to be necessary to abandon this part of the process, and experiments, therefore, were made in order to determine in what manner the silver-zinc dross could most economically and advantageously be treated.† With this object in view, experiments were made on a small scale. First, the *zinkstaub*, or silver-zinc alloy, was melted, with an addition of salt and charcoal, in cast-iron crucibles, but it was soon found that this method was impracticable. The cast-iron crucibles would melt upon the approach of the high temperature necessary for the reaction. This is caused by an insufficient supply of liquid lead, which would prevent the kettle-bottom from softening. Another obstacle to this method was that the amount of rich lead produced averaged only 63.25 per cent., with about three-fourths of the silver contained in the zinc-dust. By Flach's process 85.38 per cent. rich lead is produced, with an important amount of silver in the slag.

* Karsten Archives, 1853, 25, p. 196.

† The data of these experiments are from Dr. Wedding's yearly report to the *Preussische Zeitschrift*.

A second series of experiments were then made in graphite crucibles. It was desired, in a continual operation, to combine separation of the silver-lead alloy from the silver-zinc alloy, and at the same time accomplish a reduction of zinc. To effect this, the zinc-dust was mixed with 5 per cent. dust-coal and subjected to a high heat. In the lid of the crucible there was a pipe to conduct off the reduced zinc. The results were so unfavorable that this idea was abandoned, and experiments made to separate the silver-lead alloy from the silver-zinc alloy in wrought-iron crucibles.

328. The results hereby obtained were so good, that it has been introduced and practiced for the last three years with great success. It is to be regretted that authentic statements of expenses of this method were not to be obtained. But the fact that it is used to desilverize so large a quantity of silver-lead as is there produced, where economy is so closely pursued and a royalty is not taken into consideration, is a strong proof that it has material advantages over other known methods. Additional buildings were erected in 1872, in which the following process is conducted: The distillation-furnace is an ordinary zinc-furnace; it contains 24 muffles. Heat is produced by a gas-generator. The cast-iron crucibles are cylindric, 2.6 centimeters in diameter, 52 centimeters deep, and 2.6 centimeters thick. The zinc-dust (*zinkstaub*) is mixed with coal about the size of pease and 5 per cent. salt; the latter is decrepitated with 5 per cent. kieserite, ($Mg\ O, S\ O\ 3 + H\ O_2$.) This mass is placed in the already heated crucible, in the bottom of which crushed coke is spread 13 millimeters thick; a layer of the same thickness is spread on the top of the mass. The lid is then put on, and the charge is exposed to a low temperature for about two hours and a half; at the end of this time the rich lead will have collected in the bottom of the crucible. Eight crucibles have the capacity of a low-shaft furnace. The products are rich lead, 75 per cent. of the lead contained in the zinc-dust carrying 2.063 per cent. silver, and a residue with 25 per cent. of the lead contained in the zinc-dust.

329. The rich lead is cupelled. The zinc in the residue is distilled off in common clay zinc-muffles. Lead attacks clay, and, in the high temperature necessary to distill zinc, quickly destroys the muffle. To make, therefore, the clay-muffle practicable, a great number of experiments were made to find a suitable material to serve as a lining, which would neither be attacked by the lead, burned by the high heat, nor easily cracked. A lining possessing these characteristics was made by Herr Gerhard. He treats coke-cinder with a weak acid, heats it, and after this is made adhesible to the clay by means of a small addition of an alkali-salt, it is burned on the inside of the muffle. This is now glazed by a mixture of clay and condensed lead-fumes, when it is ready for use. These muffles have by trial-distillations proved to be good and sound after having been ten days in operation. Each muffle contains a charge of 25 kilograms residue, to which 30 per cent. of crushed coke has been previously added and thoroughly mixed.

330. The distillation lasts twenty-four hours. The products from 4 muffles are 20.2 to 36.2 kilograms rich lead, containing 3.52 to 4.01 per cent. silver. This quantity of rich lead is further increased from 8.7 to 16.2 kilograms lead, with 2.50 to 3.47 per cent. silver, by leaving the residue in the muffle and collecting the small globules of lead therein contained. The amount of raw zinc produced varies between 18.8 and 22 kilograms. This zinc contains—

1.25	per cent. lead.
0.03	per cent. cadmium.
0.19	per cent. coal and impurities.
0.00012	per cent. silver.
1.47012	

Upon cleaning out the muffle, the residue is found to have assumed an almost black color, which indicates that the reduction was about complete. The mass is, in distillation, reduced to three-fourths of its original size. Only a small amount of lead-fumes are produced in the course of distillation, but they issue forth in larger quantities when the residue is removed from the muffle as the latter is still heated.

331. This method is, for grades of lead which are comparatively free from antimony and copper, probably the most desirable in practice. Experiments are to be made at Lautenthal in order to ascertain if lead containing copper and antimony can also be worked with this modification to advantage. There is apparently no reason that it should not likewise prove a success with their silver-lead, as there the copper is estimated by the first of the three additions of zinc, and the antimony remains mostly with the poor lead. It dispenses with several by-products which cause objectionable processes to utilize them, and allows an extraction of metallic zinc. It is also preferable to the modification known as the "Balbach system." The repeated refining and liquation in furnaces and hearths is not so desirable as the use of kettles and steam for eliminating a small quantity of antimony and copper and the larger amount of zinc remaining in the desilverized lead. I mean that the latter process is more economical in regard to fuel, labor, cost of construction, and the loss of lead; as in the low temperature by which the process is conducted in kettles the loss of lead is exceedingly small.

332. The Walter Cronech Hütte, near Roddzin, was represented by samples of ore, silver-lead, commercial soft lead, silver, and litharge. These works were founded in 1864, and treat all the lead-ores that are extracted outside of the district in which the Friedrich mine is located; the latter district is reserved by the government. The smelting process is similar to that of Friedrichs Hütte. The total amount of lead produced by these two works is greater than the production at the Freiberg works, and second only, in Germany, to the works at Stolberg, near Aix la Chapelle. There were about 690 laborers employed in the Friedrich mine in 1872, who extracted 10,850,000 kilograms lead-ore.

This was reduced at the Friedrich works in seven reverberatory smelting-furnaces, five shaft-furnaces, and two cupellation-furnaces. There are also zinc-desilverization works, and the necessary auxiliary apparatuses. The production in 1869 was:

	Friedrichs Hütte. Kilograms.	Walter Cronech Hütte. Kilograms.
Lead	4,385,750	1,466,400
Litharge	865,600	579,400
Silver	5,140.5	1,938

The product for 1873 was, in both works:

	Kilograms.
Lead	7,629,150
Litharge	1,751,600
Silver	8,336.5

333. THE RHINE PROVINCES.—Although lead mining and smelting in the Aix la Chapelle-Eifel district dates from the commencement of the seventeenth century, the mines and reducing-works have been in the hands of so many different persons and corporations that their operations were necessarily very limited. It was in the middle of the present century, when large companies were formed and the many small works were consolidated, that the production of this district grew to immense proportions, and is now only second to a few English lead-smelting localities. The spirit shown there now is extremely progressive, and several important improvements in running and smelting have originated there.

334. Galena, cerusite, blende, and calamine occur in veins and irregular deposits in the neighborhood of Stolberg, on the border of the limestone and schiefer formations. Near Commern, galena occurs in buntsandstein as nodules.

335. The smelting-works of the Rhine provinces were all represented by small and incomplete collections of their intermediate and final products. Herbst & Company, from Coll in the Eifel, exhibited several specimens of ore, silver-lead, silver, and commercial lead. These works treat the lead-ores from the lead and zinc mines of Münsterfeld, near Stolberg, and Gertrudensegen, near Much. The grants for these mines were issued in 1839 and 1847, but they are not yet fully developed. The lead-ores are treated, together with Spanish ores, at the Schliessenmaar Hütte, which was founded in 1835. The ores average over 52 per cent. lead, and carry copper, antimony, and zinc. The combined roasting and reduction process is here practiced. The ores are roasted in such a high temperature that they are partly agglomerated. This is desired, and often to produce this result a small addition of siliceous ore is made. The furnace used has a double hearth, (Fortschanfelungsofen) with working-doors on one side only. The furnace is 13.5 meters long

and 3.0 meters wide. The charge is drawn every six hours. Its capacity is 5,000 kilograms in twenty-four hours, accompanied with a consumption of 12 to 13 per cent. bituminous coal. The blast-furnaces employed are, with one exception, 6.28 meters high and have one tuyere. This is a Stolberg crucible furnace; it is 6.28 meters high, 0.785 meter wide, and 1.098 meters deep. It has five tuyeres, one in each side, one in the back wall, and one in each back corner, which are all directed toward the slag-spout. The capacity of the furnace with one tuyere is 5,000 to 5,500 kilograms ore. The charge consists in 100 kilograms ore, 28.7 kilograms iron tap-cinder, 14.3 kilograms limestone, and a small amount of old lead-slag. The slag produced is a pisquisilicate.

336. *Zinc-desilverization.*—The silver-lead is desilverized by the zinc method, with the use of chemical agents to dezinckify the poor lead and to separate the zinc-silver alloy from the enriched silver-lead. The manipulations are as follows: 15,000 kilograms of the silver-lead—containing 0.05 per cent. Ag = 14.5 oz., 0.5 per cent. antimony, 0.01 per cent. copper—are melted in a kettle 2.52 meters in diameter and 0.60 meter deep; at the end of ten hours the lead is in a molten condition and the abzug is drawn off. The zinc is added in three portions. After the temperature has been sufficiently raised, the first portion of 90 kilograms block-zinc is thrown in the liquid lead. After this has melted it is well stirred for twenty minutes; the mass is then allowed to cool slowly for twenty minutes, when the copper-scum (kupferschaum) will have formed. The copper and gold contained in the lead is herein concentrated. The copper-scum is drawn off; but, as the first quantity (90 kilograms) of zinc formed an alloy with the lead, &c., necessary for a separation of copper, gold, and zinc, and a great part of the zinc is still in the lead, the second addition is only (50 kilograms) zinc; this is added after the temperature of the metal bath has first been raised. Twenty minutes are consumed in stirring. The alloys are cooled for two hours, and the zinc-silver alloy (zinkschaum) is then taken off. The kettle is now refilled with silver-lead from a previous operation, assaying 0.0025 per cent., or 3 oz. silver. The third addition of zinc is 6.7 kilograms, by which the same operations are performed as by No. 2.

337. The products are copper-scum, in which the gold is concentrated, 500 kilograms; zinc-scum, containing the silver, 3,000 kilograms; poor lead = zinc-lead alloy, containing 0.00062 per cent. = 3 dwt. 13.99 gr. Ag, and 0.77 per cent. zinc, 12,500 to 13,000 kilograms. The time consumed in treating 15,000 kilograms silver-lead is twenty-four hours.

338. The poor lead remaining in the kettle contains 0.5 to 0.7 per cent. zinc and a small amount of antimony; the former is eliminated by means of a mixture of 150 kilograms lead-sulphate (from the sulphuric-acid manufactories near Stolberg) and 50 kilograms of salt. It is added in small quantities, the mass being continually stirred until a test taken out in an iron spoon does not show the silky appearance pecu-

liar to lead containing zinc. This operation lasts about twenty-four hours. The lead-sulphate and soda-chloride react upon one another, producing soda-sulphate and lead-chloride. The latter is decomposed by zinc-forming lead and zinc-chloride. The result is about 175 kilograms of scum, which contains 25 per cent. of metallic lead. After this scum has been removed the antimony, which has not been materially affected by the chlorine salts, is eliminated by stirring 40 kilograms of unslaked lime with the remaining lead. The lime absorbs the antimony, and in about thirteen hours the operation is complete. The lead is used in the manufacturing of white lead.

339. *Dezinckifying the zinc-scum.*—A charge of 1,500 kilograms zinc-scum is melted in an iron kettle, similar to the kettle in which the copper-scum was liquated. It is then treated with 450 kilograms carnallit ($2\ Mg\ Cl + K\ Cl + 12\ H_2\ O$) from "Stassfurt," and 150 kilograms salmiac. The temperature is kept for three days at about 400° C., and the result of the reaction, which occurs in consequence of a vigorous stirring, are chloride of zinc, ammonia, and 1,300 kilograms enriched silver-lead. The latter is tapped off by means of an iron pipe from the kettle-bottom. The residue contains a considerable amount of silver-lead, and to extract this 300 kilograms of zinc-scum are added to and melted with the residue. This, after having been well stirred, is tapped off. The products are about 1,500 kilograms enriched silver-lead, assaying 2.7 per cent. = 787 oz. 2 dwt. silver, which is cupelled, and a residue containing 8.10 per cent. lead with 2.7 per cent. silver, which is smelted with the liquated copper-scum in a shaft-furnace.

340. *Liquation of copper-scum.*—The copper-gold scum (kupferschaum) is liquated in oblong kettles. These are 2.5 meters long, 1.6 meters wide, and 0.87 meter deep. The lead herefrom is added to the desilverization-kettle after the second zinc-charge. The copper-gold-zinc residue is then smelted in a shaft furnace with 25 per cent. iron tap-cinder and 50 per cent. lead-matte.

341. The products herefrom are silver-lead containing 0.7 to 0.8 per cent. = 2.33 oz. 6 dwt. Ag, and a small amount of gold and matte, with 9.8 to 10 per cent. copper.

342. The lead is treated with zinc, &c., as above described, (with the exception that the first scum is not treated separately from the following two;) the silver produced contains 0.001 per cent. gold. The matte is smelted in a shaft-furnace with non-argentiferous lead-ores and products. The lead from this smelting is refined and is then commercial lead. The matte contains 20 per cent. copper and is roasted with salt, &c., preparatory to a humid process. The dross produced in dezinckifying the poor lead is smelted in a shaft-furnace with the antimonial dross and iron tap-cinder, whereby the zinc is partly volatilized and partly slagged. The resulting lead, containing 1 to 3 per cent. antimony, is melted in an iron kettle, and the greater portion of the antimony is eliminated with unslaked lime. The lead obtained, although of an infe-

rior quality, is sufficiently soft to be rolled into sheet-lead. The dross is smelted in a shaft-furnace with iron tap-cinder. This lead contains 10 to 14 per cent. antimony, and, in order to oxidize the impurities, it is melted in an iron kettle and treated with 0.5 per cent. soda saltpeter. This produces lead with 10 to 12 per cent. antimony, which is used for making type. The dross from this manipulation is set aside until a large quantity has accumulated, when it undergoes the same operation. This method is, on account of the time consumed, only suitable for small works. It has, however, the advantage of not requiring a large outlay, is simple in its manipulation, and, on account of the very low temperature, 400° C., the loss of lead and silver is insignificant.

	A.	*B.*	*C.*	*D.*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Antimony	0. 046	0. 003	0. 0016—0. 00008	0. 0020
Copper	0. 008	0. 007	0. 0004—0. 0005	0. 0029
Iron	0. 004	0. 005	0. 0019—0. 0023	0. 0023
Zinc	0. 777	0. 003		0. 0009
Bismuth			0. 0023—0. 0024	0. 0008
Thallium			0. 0003	
Silver	0. 00062	0. 00062	0. 0005	0. 0005

The above analysis will present an insight into the desilverization process practiced at Call. *a* is desilverized lead, before the elimination of zinc; *b* is lead refined by means of lead-chloride and lime; *c* is lead refined with lead-sulphate and salt; *d* is a late analysis of the refined lead. These works employed in 1872, 62 workmen; they produced 550,000 kilograms lead.

344. Die Stolberger Actien-Gesellschaft für Bergbau, Blei- und Zinkfabrication.—"The Stolberg Stock Company for Mining and the Production of Lead and Zinc," exhibited specimens of ores and commercial soft lead.* This company has its headquarters in Aix-la-Chapelle, owns bituminous-coal mines near Stolberg and Dortmund, and also lead, zinc, and iron-pyrites mines near Stolberg, Ehrenbreitenstein, Barmen, Ramsbeck, Brilon in the Harz, and in Spain. It also smelts ores from Sardinia.

*The analysis accompanying the latter showed the following percentage of foreign substances in 1,000,000 kilograms:

No. 1.		No. 2.		No. 3.	
	Kilograms.		*Kilograms.*		*Kilograms.*
Sb	39. 1	Sb	40. 1	Sb	31. 7
Cu	8. 4	Cu	20. 6	Cu	trace.
Zn	7. 8	Zn	22. 1	Zn	2. 2
Fe	6. 8	Fe	14. 1	Fe	4. 5
	62. 1		96. 9		38. 4

The ores treated are of a varied composition; a large proportion, however, carry a considerable amount of copper, antimony, and zinc. Four calcining-furnaces are used for calamine.

345. Twenty furnaces are employed to roast lead-ores and blende. The first are treated in double-hearthed reverberatory, and the latter in furnaces according to Hasenclever and Helbig's system; models of the latter were exhibited. The construction of these furnaces is illustrated in Figures III and IV. It is asserted that it is easily manipulated, and that it roasts well—*i. e.*, blendic ores with 33 per cent. of sulphur are roasted, so that, after the operation, they contain only 1.2 per cent. (?) sulphur, and permits the use of the sulphurous-acid fumes for the manufacture of sulphuric acid. The disadvantages compared to the Gerstenhofer furnace are, the large cost of construction, consumption of fuel, its small capacity, and, as the ore is liable to adhere to the sliding-surface and partitions, a moderate amount of lead in a substance would disqualify it for treatment in this furnace. The last objection applies also to a chloridizing roasting. The muffle roasting-furnace, standing in connection with a tower, as formerly constructed by Hasenclever and Helbig,* did not allow of the good roasting of blende in the tower, the temperature in the same not being sufficient for this purpose; zinc only melting on the lower plate and lead scarcely on the upper. After the hot gases from the muffle were employed for heating the tower, and iron plates used instead of fire-clay, the roasting was better, and blende, containing 30 per cent. sulphur, only contained 19 per cent. sulphur on arriving at the foot of the tower, at the end of the muffle 8.75 per cent., and when taken from the furnace only 1.04 per cent. (?) The roasting gases containing 6 per cent. sulphurous acid, could also be used to advantage for the manufacture of sulphuric acid. The canals, however, proved to be inadequate for the gases of combustion; the cinders and dust coming from the fire-place could not be removed during the operation of roasting, and they easily obstructed the passage between the iron and fire-clay slabs. This caused cracks, and sulphurous acid escaped with the gases from the fire-place. This disadvantage has been avoided by the newest method of construction, (Fig. I:) R, charging-funnel for holding the ore, from which it glides through an inclined canal, which is 1.8 meters wide, 0.5 meter high, and 9 meters long. The incline of the canal is 43°. The ore is heated from below by the gases from the fire-place passing through the canal. The gases produce a temperature in the ore-canal sufficiently high to melt antimony in the upper part of same. H, 50 partition-walls which reach to within a few centimeters of the bottom wall of the canal. They cause the ore to pass through the canal in a thin layer, and also cause the sulphurous acid evolved to pass over the ore in a roundabout manner—that is, through apertures alternating with each other on the sides of the partition-walls. The roasting

* The description of Hasenclever and Helbig's improved roasting-furnace is from the *Zeitschrift des Vereins Deutscher Ingenieur*, 1872, p. 505.

gases, rich in sulphurous acid, escape at S into a cooling-chamber covered with iron plates, upon which the ore is dried before entering the furnace. Entrance can be obtained to the different compartments of the canal by means of holes on the sides, which are closed by slides. Entrance is also obtained in the same manner to the fire-canals. I, hollow discharging-roller, kept cool by air passing through from side to side; it is revolved by a small water-wheel. The motion is not continual, but periodical. As soon as a bucket fills with water, the wheel revolves half the way round, and with it the discharging-roller, whereby the ore is discharged from the inclined canal into the muffle *b;* the rest of the ore in the inclined canal gliding down as fast as the roller discharges. The muffle *b* is 6.5 meters long, 1.8 meters wide, and 0.4 meter high, and has five working-doors. The ore is spread out in the muffle every two hours and gradually shoved to the rear, where it falls through an opening on the lower hearth, *a*, which is directly heated by the flames from the fire-place. The hearth *a* is 5.7 meters long and 0.4 meter high. The ore is here completely roasted and gradually shoved toward the fire-bridge. The sulphurous acid evolved on the lower hearth passes off with the gases of combustion through *e*, *c*, *d*, and *m*, into the chimney; *l*, Boätuis gas-generator, hot air passing in over the generator; *f*, working-door; *k*, door for charging generator with fuel. Blende containing only 30 per cent. sulphur is said to contain 10 per cent. sulphur when reaching *g*, 6.4 per cent. at the rear of the muffle, and 1.2 per cent. (?) on reaching the fire-bridge.

346. The lead-ores treated at these works are prepared for the smelting operation by roasting in reverberatory furnaces. These have one hearth and four working-doors on each side. They are 10.8 meters long and 4 meters wide. Their capacity is 3,330 kilograms ore in twenty-four hours, with a consumption of 25 to 26 per cent. bituminous coal. Twelve shaft-furnaces are used to smelt the roasted ore. Ten of these are of the construction known as the Stolberg furnace. Those used here are crucible-furnaces with four tuyeres in the back wall. Two are small Raschette furnaces, 1.26 meters wide and 1.57 meters deep. The charge is composed of 40 to 50 per cent. iron tap-cinder, 8 per cent. limestone, 20 per cent. lead-slag, 22 per cent. cokes. Cerussite is made into balls with powdered iron tap-cinder and lime, and is then smelted in the same manner as galena. The capacity of the Rachette furnace is 25,000 kilograms ore in twenty-four hours. The consumption of fuel is the same as in the Stolberg furnace.

347. Both the pattinsonizing and the zinc-desilverization methods are used. The purer grades of silver-lead are desilverized by means of zinc in iron kettles. The charge for the latter process is 12,000 kilograms. It is necessary with silver-lead containing a large quantity of antimony to eliminate the latter after the abzug, formed by melting, has been removed, and before the first addition of zinc, by conducting superheated steam through the molten metallic mass, whereby the antimonial lead

is stirred up and brought in contact with the air, and the antimony oxidized, together with a small quantity of lead. This dross is drawn off, and the lead is desilverized by three additions of zinc. The amount of zinc consumed with silver-lead containing copper averages 1.2 per cent.

348. The poor lead is dezinckified by means of superheated steam. The zinc-scum is liquated in iron kettles, and then treated with steam, (*vide* Lautenthal;) the rich lead is cupelled. The zinc-dust is treated, according to Flach's method, in a shaft-furnace with three tuyeres and a low pressure of blast. The charge is 100 zinc-dust, 50 iron tap-cinder, and a small quantity of the upper part of the cupellation-hearth. The resulting silver-lead is cupelled. This process is said to possess several advantages, such as small cost of construction, requires but few workmen to conduct it, and gives immediate results, 83 per cent. of lead being extracted. But it has also important disadvantages, and it is a disputed point whether it is more desirable than the Lautenthal method. It is, in all probability, far inferior to the method practiced at Tarnowitz.

In order to avoid a great volatilization of lead the pressure of the blast must be made small, but in this case the amount of zinc volatilized is also diminished; only very little silver is volatilized, but large salamanders are formed, which are rich in silver but difficult to work. The zinc is partially slagged and partially volatilized. The slag and salamanders are both added in small quantities to the ore-smelting.

349. The silver-lead free from impurities, viz, antimony, copper-arsenic, &c., is pattinsonized in two batteries; each battery is composed of two kettles, viz, the melting and the crystallization kettles. The method is the so-called "mechanical pattinsonizing." The system used at Stolberg was invented by M. Boudehen. It is also applied at Hozappel and Rouin. The* stirrer in the crystallization-kettle is moved by a vertical hollow shaft, "within which there is a hollow shaft. By a well-known arrangement of bevel-wheels, these shafts are made to revolve in opposite directions. On the lower part of the outer shaft, within the pot, is fixed a stirrup-like frame, from the sides of which project short flat-edged scrapers; on the inner shaft are fixed flat arms of equal length, arranged spirally, and with their sides oblique. Engine-power of 5 or 6 horses is required to drive this machinery. It is asserted that the cost of manual labor is only half of that in Pattinson's process, and the total saving is estimated at 20 francs = $4 per ton." The considerable outlay for machinery and skilled manual labor appears to be the principal objection to this method. In Stolberg the charge is 12,000 to 125,000 kilograms silver-lead. The silver-lead is melted in the upper kettle, A,† and then tapped through the iron pipes into the lower kettle, B, which has previously been heated. In order to reduce the

* The following description and drawing of apparatus are from Percy's Metallurgy of Lead, page 143. The drawing given is Jordan's system. Boudehen's is the same in principle.

† See Figures 7 and 8.

temperature of the metallic liquid an addition of silver-lead is made. The stirrer is then set in motion and small jets of water thrown upon the molten alloy. At the end of two hours the mass will have become pasty, when the stirrer and water-streams are stopped and the mother-liquid is tapped into a heated pot, *c*. An iron hook is set in the lead while molten, and when the lead has cooled it is lifted out by means of a tackle. A fresh quantity of silver-lead, about 3,000 kilograms, assaying about the same in silver as the remaining crystals, is added from the melting-kettle, A, to the crystallizing-kettle, B; during this operation the motion of the stirrer is reversed. The molten alloy soon liquefies the crystals, when the already-described operation is again performed. After this operation has been repeated seven times, the poor lead contains but 0.0036 per cent. = 1 oz. 23.47 grs. Ag. The crystals are melted, tapped off, taken to another kettle for remelting and casting in pigs. An obstruction to the process is thus avoided. The mother-liquid is enriched in eight operations. The mother-liquid resulting is then returned to the kettle and further enriched in five operations; it contains 2.4 per cent. = 699 oz. 12 dwt. Ag. Eighty muffle-furnaces are employed in reducing zinc-oxide. Regenerative furnaces are a to several of these, and are said to give very economical results.

350. These works produce a greater amount of lead than any other establishment in the world. Their production in the last few years has averaged: Lead, 10,550,000 kilograms; silver, 7,850 kilograms; zinc, 7,600,000 kilograms; 1,850,000 kilograms was manufactured into sheet-zinc.

351. The Rheinisch-Nassauische Berg-und Hütten-Actiengesellschaft was represented by a collection lead and zinc ores, and a few intermediate products, viz, commercial lead and silver. This company was formed on January 1, 1873, by a consolidation of the Eschweiler Gesellschaft für Bergban und Hütten, located at Stolberg, and the Holzappeler Blei und Silber-Bergwerksgesellschaft, located at Holzappel. It owns lead, zinc, and iron-pyrites mines near Stolberg, Bensberg, and Wiesloch. The ores from these mines, together with ores from Montevecchio in Sardinia, Gar Rouban in Algiers, Utah, and Nevada, are treated at the Binsfelohammer Hütte, near Stolberg, and the Wilhelms Zinkhütte near Eschweiler. The Holzappeler Hütte treats the ores from the lead-mines near Holzappel and Obernhof. The ores at Binsfeldhammer are worked by the combined roasting and reduction process.

352. The roasting-furnaces are 6.3 meters long and 2.3 meters wide; they are double-hearthed, and each hearth has three working-doors, on one side only. The roasted ore is smelted in shaft-furnaces. These were all originally of the Stolberg pattern, but round shaft (Pilz) fur naces have recently been introduced. The silver-lead is desilverized by means of zinc. Superheated steam is used as the oxidizing medium. The zinc-dust from liquation of the zinc-scum (*zinkschaum*) is smelted with iron tap-cinder in the reverberatory furnaces that were formerly used for the smelting of ore, according to the " French process."

Siemens's regenerative gas-furnaces have been in operation at Wilhelms since 1862.

353. The gas generative and regenerative systems have proved to be very advantageous for zinc-furnaces in the past, and, as the price of coal will probably continue to grow larger without a corresponding increase in the value of zinc, the gas generative or regenerative system will, in the future, be necessary to an economically successful working of zinc-ores.

354. HOLZAPPEL.—The combined roasting and smelting process for lead-ores has taken the place of a modified Carinthian smelting process in reverberatory furnaces at Holzappel. The ore is galena, with blende and copper pyrites. The gangue is quartz, siderite, and argillaceous slate. The ore is roasted and agglomerated in single-hearth reverberatory furnaces, having five working-doors on each side. The hearth is 9.41 meters long and 3.14 meters wide. Its capacity is 6,000 kilograms in twenty-four hours, with a consumption of 17 per cent. bituminous coal. The ore remains in the furnace thirty hours; a charge of 750 kilo grams is drawn every six hours. The roasted agglomerated ore contains about 5 to 6 per cent. of sulphur.

The roasted ore is smelted in Stolberg crucible shaft-furnaces. They have two tuyeres, and are 4.079 meters high; front width, 0.785 meter; back width, 0.941 to 1.25 meters. The charge is composed of 750 kilograms ore, 250 kilograms iron tap-cinder, 500 kilograms lead-slag, 125 kilograms limestone, 135 kilograms coke, and small variable quantities of cupellation, hearth, and furnace accretions.

The silver-lead, containing 0.01 per cent.=2 oz. 18 dwt. 4.80 gr. silver, is pattinsonized. Mechanical pattinsonizing was first introduced at these works. The mechanical stirrer used was invented by M. Boudhen. The process is similar to that at Stolberg.

355. This company produced in 1872—

	Zinc.	Lead.	Silver.
Binsfeldhammer Hütte ......kilos..	....	1,200,000	....
Wilhelm's Hütte ....kilos..	950,000	....	....
Holzappel ....kilos..	....	300,000	300

Making a total production of zinc, 950,000 kilograms; lead, 1,500,000 kilograms; silver, 300 kilograms.

356. The Mechernicher Bergwerks Actien Verein, of Mechernich in Commern, was represented by maps, illustrating the size and character of their mines, ores, silver-lead, commercial lead and silver. This company works the large lead-mine "Meinerzhagener Bleiberg," and the smelting-works at Mechernich. The Meinerzhagener Bleiberg mine was originally divided into several smaller mines, dating from the seventeenth

century, which were consolidated into one in 1857. The mining consists in both surface and subterranean working. The sandstone stratum is over 20 meters thick, and is impregnated with small galena nodules, averaging from 2 to 4 millimeters in diameter. The size of the levels and the condition of the atmosphere in the mine permit the use of small steam-engines to draw the ore-cars. Rock-drilling machines are used, and the blasts are exploded by means of electric sparks. The levels, &c., are lighted with gas. There were 2,700 workmen employed in this mine in 1872, who extracted 4,700,000 kilograms ores assaying from 1.3 to 2.0 per cent. lead. In ten hours 950 centimeters of ore and gangue are mined. The same quantity of ore is dressed in eighteen hours. The concentration is carried to 57 to 60 per cent. lead.

357. The ore, which is composed chiefly of galena, silica, and alumina, is treated according to the combined roasting and smelting process. It contains but a very small quantity of copper; which removes the necessity of retaining a large amount of sulphur in the roasted ore, in order to concentrate the copper in a matte; and is free from those minerals, the component parts of which form combinations with silica, requiring a high fusing temperature, (blende, calcite, &c.,) and a large consumption of fuel, accompanied by an increased metallic volatilization. In consideration of this the ore undergoes a "slag-roasting."

358. Double-hearthed reverberatory furnaces, (Fortschaufelungsoefen,) 10.4 meters long and 3.76 meters wide, were formerly exclusively used; but lately a furnace whose hearth is 22 meters long has been erected. It is superior to the short ones, inasmuch as the ore does not so easily agglomerate in the preliminary periods, whereby a siliceous crust would form and prevent a further oxidization. In this long furnace the ore is oxidized so gradually that the roasting progresses without interruption for six days; whereby the sulphide of lead is converted into sulphate, and a small amount of oxide of lead. As the charge is moved toward the fire-bridge the high temperature causes the silicic acid to unite with the lead-oxide, and to decompose the sulphate of lead, forming a homogeneous basic lead-silicate, containing minute particles of undecomposed galena, with the following composition:

8 to 9 per cent. $Al_{2}O_3$.
23 to 24 per cent. $Si\ O_2$.
60 to 61 per cent. Pb.
1 to 1.5 per cent. S. = 11.2 to 7.5 sulphide of lead.

The furnace contains 40,000 kilograms ore. One thousand five hundred kilograms roasted ore is drawn, and 1,500 kilograms raw ore is charged, every six hours, making the capacity of the furnace 7,000 kilograms in twenty-four hours, with a consumption of 13 to 15 per cent. bituminous coal. The last furnace erected is 24.5 meters long. It is desired to conduct the roasting slower, and, by carefully regulating the temperature, obtain a product containing still less sulphur. The reduction of the ore occurs in Stolberg shaft-furnaces with four water-tuyeres

5.02 meters high, 1,596 meters wide, and 1,255 meters deep. One tuyere is placed on each side and the other two in the back corners; they are all directed toward the slag-spout. The blast is 0.25 meter water-column.

The charge, in June, 1871, was a normal one and consisted of:

	Parts.
Roasted ore, (agglomerated,) with 60 to 65 per cent.	100
Old slime, with about 20 per cent. lead	28.5
By-products, from the zinc desilverization	20
Iron slag, from puddling-furnace	50
Furnace accretions	16
Limestone	48
Pig-iron, to decompose a small amount of galena remaining in slagged ore	45
Coke	20

The slag from this smelting was composed of—

	Per cent.
SiO_2	38.2
FeO	28.71
CaO	19.36
MgO	0.79
Al_2O_3	11.44
$Cu+Pb$	1.5
	100.00

The products are a small amount of lead-matte, containing 10 per cent. lead, a very small quantity of copper, and 20 per cent. sulphur. The matte is roasted several times in stalls and then smelted. The composition of the charge is:

Roasted lead-matte	100.00
Iron-slag, from puddling-furnace	17.77
Limestone	17.77
Coke	11.11

The lead from the matte-smelting is used in the manufacture of shot. The matte is repeatedly roasted and smelted until the contents of lead is reduced to 20 per cent., and the copper is concentrated to 1 per cent., when it is laid aside.

The silver-lead from the ore-smelting, containing 0.02 per cent. = 5 oz. 16 dwt. 14 gr. silver, is desilverized by means of zinc.

359. The process of desilverization is about the same as that practiced at Lautenthal. The charge is 30,000 kilograms; after this is melted in an iron kettle and the abzug removed, 225 kilograms of zinc are added; when the zinc has melted it is stirred for thirty minutes and then allowed to slowly cool for about eight hours. The solidified silver-zinc alloy is now removed.

The second addition of zinc is 75 kilograms, the third is 24 kilograms. The time allowed for cooling, after the second and third addition of zinc, is eight hours. This is a waste of time, as the separation of the different alloys occurs in a much shorter period when repeatedly stirred and the zinc-scum removed. A saving of labor is hardly the object sought for.

360. The poor lead is dezinckified by means of superheated steam, the desirability of using steam being increased by the lead containing a small quantity of antimony and nickel. The zinc-scum (*zinkschaum*) is liquated in iron pipes, which are inclined at a small angle. The resulting lead is desilverized with the silver-lead from the ore-smelting; the residue remaining in the iron pipes (enriched silver-zinc alloy) is smelted in a shaft-furnace.

The furnace is first charged with 100 per cent. iron tap-cinder and 20 per cent. coke. When the slag flows freely, the silver-zinc alloy is charged, commencing with 25 per cent. The normal charge consists in—

Silver-zinc alloy	100
Lead-matte, containing 9 to 10 per cent. lead	40
Iron tap-cinder	90
Coke	16–18

In order to avoid an unnecessary volatilization of lead, the pressure of the blast is not permitted to exceed 0.131 meter water-column. The lead assaying 2 to 0 per cent. = 583 oz. silver, is poled and cupelled. The copper-lead matte, when a sufficiently large quantity has accumulated, is smelted in a shaft-furnace with the following products:

Copper-lead matte	150
Old lead-slag	30
Iron tap-cinder	70
Fumes from condensation-chambers	50
Sweeping	100
Coke	40

The pressure of blast is 0.13 meter water-column. The silver-lead is cupelled. The matte, containing about 50 per cent. copper and a small quantity of silver, is sold. The loss in lead in 1870 was estimated at 9.3 per cent.

361. The production of these works for 1872 is estimated at 1,400,000 kilograms lead, 600 kilograms silver.

362. NASSAU.—The "Emser Blei und Silber Hütten" exhibited a systematic collection of dressed ores and several metallurgical products, among which were the following: Fine silver; soft lead, 99.99 per cent. being pure lead; pulverized litharge, with 92 per cent. Pb. and 8 per cent. O; prime red litharge, with 92 per cent. Pb. and 8 per cent. O; cupriferous litharge, with 91 per cent. Pb., 1 per cent. Cu., and 8 per cent. O; lump litharge, with 92 per cent. Pb., and 8 per cent. O; "zinc-

yellow," (produced in the zinc-desilverization process by the dezinckification of the desilverized lead by means of steam,) containing 60 per cent. zinc oxide and 40 per cent. lead oxide.

363. The Emser Hütte was founded in 1769, and the ore was smelted in reverberatory furnaces up to about the year 1835; the iron reduction process of smelting was then introduced, and the smelting operations conducted in one-tuyered blast-furnaces of the old Harz pattern, which were succeeded by Vogel's furnace with two tuyeres. The latter furnace was much more economical as regards the consumption of fuel than the former; the loss of lead was also diminished by their use. Within the last few years the iron reduction process has been done away with and the combined roasting and reduction process has taken its place. The ore assays 50 per cent. lead and 0.05 per cent. = 14 oz. 11 dwt. 14 gr. silver; it carries a considerable amount of blende, copper pyrites, tetrahedrite, and siderite.

364. It is roasted in single-hearthed reverberatory furnaces, (*Fortschaufelungsoefen*,) 7.85 meters long and 4.08 meters wide. They have working-doors on both sides. Its capacity is 4,800 kilograms ore, with a consumption of 25 per cent. bituminous coal. The roasted ore contains 5 to 4.5 per cent. sulphur. The fumes from roasting were in 1871 permitted to escape into the air, whereby the loss of lead, &c., was greatly increased.

365. Two twelve-tuyered Rachette furnaces, 4.393 meters high—at the bottom, 2.823 meters long, 1.098 meters wide; at the top, 2.994 meters long, 1.569 meters wide—are used for the reduction of the ore. The charge is composed of—

100 parts roasted ore.
133 parts slag from same operation.
50 parts reheating slag.
10 parts lime.
8 parts lead-flux.
30 parts coke.

The capacity of each furnace is 45,250 kilograms charge in twenty-four hours. The pressure of blast is 0.013 meter quicksilver-column. It was intended in 1873 to erect a Pilz furnace, with the hope of materially diminishing the amount of zinc-accretions, &c.

366. The lead-matte, containing 4 per cent. copper and 8 per cent. lead, is roasted in stalls and smelted. The silver-lead from the matte-smelting, on account of its containing a considerable amount of copper, is not desilverized with zinc, but is sent directly to the cupellation-furnace. The concentrated copper-matte is sold.

367. The silver-lead from the ore-smelting is desilverized by means of zinc. On account of the small quantity of silver-lead to be treated, the battery consists of only four desilverization-kettles, two for treating the silver-lead, one for liquating the lead in the zinc-scum, and one in which the zinc, &c., in the zinc-dust (zinkstaub) is oxidized. The kettles are

1.7 meters in diameter and 1.1 meters deep. The charge is 5,000 kilograms. The zinc is added to the molten silver-lead in three portions. The amount of zinc used is 200 kilograms = 1.3 per cent.

The alloy (copper-scum) formed by the first addition of zinc holds the gold contained in the silver-lead. This is kept and treated by itself, but in a similar manner as the zinc-scum. The silver-zinc alloy from the second and third additions is first liquated in an iron kettle. The resulting lead is treated with a second and third portion of zinc. The zinc-dust is removed to the fourth, or rich, kettle, and, after having been brought to a cherry-red heat, is violently stirred with superheated steam. The zinc and a portion of lead are hereby oxidized. The lead containing 2 per cent. = 583 ounces silver is cupelled. The rich oxides are smelted in a two-tuyered furnace 4.86 meters high, 0.13-meter pressure of blast, quicksilver-column. It was formerly used for ore-smelting. The charge is composed of—

100 parts rich oxides.
100 parts iron tap-cinder.
100 parts lead-slag.
30 parts coke.

It is asserted that the formation of salamanders is small, but an important feature of this process is the volatilization of silver. The fumes assay 0.004 per cent. = 1 oz. 3 dwt. 7 gr. silver. The desilverization-lead is treated with steam, whereby the zinc and antimony are oxidized. Rachette furnaces with twelve tuyeres were first employed at Ems.

368. In 1872 these works produced—

	Kilograms.
Lead	1,080,000
Litharge	1,710,000
Silver	3,050

CHAPTER IX.

AUSTRO-HUNGARIAN EMPIRE EXHIBITS.

CONDITION OF METAL-INDUSTRY; DISPLAY; EXHIBITS OF THE PRIBRAM SMELTING-WORKS, KSCHEUTZISCHER, ZECHE AND MIES, BRIXLEGG SMELTING-WORKS, JOCHBERG SMELTING-WORKS, MÜHLBACH SMELTING-WORKS, BLEIBERG SMELTING COMPANY-EGGER SMELTING-WORKS, J. RAINER, SMALLER CARINTHIAN SMELTING-WORKS, RAIBLE SMELTING-WORKS, PUNTSCHARD WHITE-LEAD WORKS, F. P. HERBST, LUDWIG KURSCH SMELTING-WORKS, KRAIN LUDWIG'S KURSCH ZINC-WORKS, FROUE, BULGARIA, ROYAL HUNGARIAN MINT; SMELTING-WORKS AT SCHEMNITZ, KREMNITZ, TARNOWITZ, AND NEWSOHL, TAJORA; METALLURGICAL PROCESS IN THE LOWER HUNGARIAN MINING-DISTRICTS, WALDBURGERSCHAFT SMELTING-WORKS, TRANSYLVANIA, NAGY BARYA.

369. Lead-metal industry in the Austrian-Hungarian Empire has a very ancient origin, but, on account of a lack of large ore-deposits, it has never grown to extensive dimensions. It is chiefly owing to the many important improvements, made by Peter Ritter v. Rittinger, by means of which the ores are carefully dressed and the obnoxious minerals separated from the valuable elements, that they are enabled to conduct the smelting processes in an economical and profitable manner. The lead and silver mining and smelting centers in Bohemia and Hungary have, unfortunately, been without railroad communications, which have, in some respects, greatly retarded their development. A railroad was finished and opened to Schemnitz last summer, which will enable the reducing-works to operate on quite an enlarged scale. The government has already adopted measures to consolidate the reducing-works in and near Schemnitz into one.

370. The empire was well represented at the Exposition in Group I, and it was greatly regretted that the mining and metallurgical products were not exhibited so as to form a connected display, and thus present one large exhibit instead of the many lesser ones. The products of each separate district were scattered through the Austrian portion of the "Industrial Palace," presenting a striking contrast to Germany's display, and making it difficult for the visitor to obtain a comprehensive oversight of the whole by comparison.

371. BOHEMIA.—The Pribramer Silberhütte was represented by plans of the smelting-works; statistical map of production, embracing the receipts and expenses, gain and loss, for each year from 1751 to 1871; charts illustrating the different steps in dressing the ores, and each manipulation in their reduction, and systematically-arranged collections of vein-pieces,

(41;) dressed ores, (50;) intermediate and final metallurgical products, (52;) models of machinery for dressing ore; and model of the newly-erected large cupelling-furnace.

372. A large pyramid, placed opposite, and similar to that from Brixlegg, attracted attention. The body was composed of vein-pieces, ores, and products; a piece of silver from the German cupellation-furnace formed its apex. This exhibit was in itself a model of completeness, and showed a scientific treatment of the subject. The following have been selected from this display as being of especial interest:

Commercial antimonial lead, noted for its large percentage of antimony, (18 to 20 per cent.;) silver-lead, soft lead, commercial lead, from pattinsonizing, produced by reducing and pattinsonizing the rich litharge. Black, red, and green litharge; the former is reduced and produces antimonial lead; the two latter are articles of commerce. Silver, from German cupellation-hearth, in the form of a large cake, about 3 feet 6 inches in diameter and 2 to 4 inches thick. It weighed 1,015 Zoll. pounds = 507.5 kilograms, and was valued at 4,570 gulden, (Austrian.) Near the edge of the silver-cake there were large pyramids, formed by sprouting while cooling. The pyramids were from 4 to 8 inches high. There were also bricks of refined silver exhibited.

373. In addition to the enumerated products, there was a model of Rittinger's continual-acting percussion-table, in one-third of the natural dimensions. This table is intended to classify sorted slimes. The frame of the bed is of wrought-iron, and it is suspended by four hooks from four iron pillars. The floor of the bed was, in the model, of marble. Its capacity is 0.063 to 0.126 centimeter slime in one hour. It concentrates pure slime to 60 to 70 per cent. of lead.

374. There was also exhibited a model of the cupellation-furnace, in one-sixteenth of its natural dimensions, erected in 1872 by Herr Čermak. This furnace (see drawings) is rectangular, with a surface of hearth equal to 12 square meters. There are two movable hoods, each covering one-half of the furnace. This furnace is intended for a charge of 25,000 kilometers = 24.63 tons English lead. It has four fire-places; these are placed, two in each end; the doors are in the front and rear of the furnace. Either wood or bituminous coal can be used as fuel. The lead-fumes are caught in small hoods, hung over the litharge-opening, and led into the main escape-pipe for the gases and fumes; this is cast-iron, and is conducted through the blast-canal, thus warming the blast. It was intended to construct three similar furnaces in 1873–'74, with gas-generating furnaces attached. The drawing at the end of this report is a copy of the drawing by which the furnace was built.

EXPLANATION OF THE DRAWINGS, FIGURES IX TO XVI, OF THE NEW CUPELLATION-FURNACE BUILT AT PRISBAM IN 1872.

A, hearth made of marl.
B, hearth made of slag.

C, foundation, with holes, *f*, for escape of moisture.

b, two doors for charging or watching the process.

D, two movable hoods; *d*, sections of the same.

E, four iron columns supporting an iron rail, upon which rest the pulleys that raise the hoods.

g, small hood overhanging litharge-doors, F, and leading into G for escape of furnace-fumes.

H, iron pipe containing blast; this is placed in the canal, G, by means of which the blast is heated. *h*, tuyeres.

K, door to fire-place. *k*, fire-grate, with blast from *l m*, ash-pit.

It is greatly to be regretted that the results obtained with this furnace at Pribram were not to be had. But it is highly probable that it would be very advantageous for works where large quantities of silver-lead are cupelled, as at Pribarm. There must be a great saving of fuel and labor when cupelling large quantities of silver-lead, especially if it is poor in silver, when compared to the method often practiced of repeatedly adding fresh quantities of silver-lead, which has the effect of cooling the molten mass, and producing an impure litharge throughout the first part of the process. The concentration of the silver cannot be carried in this furnace beyond certain limits, owing to the increased temperature, and proportionate consumption of fuel necessary to heat the resulting small amount of silver in the large hearth.

375. Latest improvements in the metallurgical process.—Since the close of the year 1871, the combined washing and smelting process has taken the place of the iron-reduction process, in use up to that time. Long reverberatory roasting-furnaces are used for roasting ores, and *Rundöfen* (cylindrical blast-furnaces) with seven tuyeres, for the smelting and reduction of the roasted ore. In consequence of this change, less lead-matte had to be roasted and reduced by smelting, whereby the reduction was accompanied with a smaller amount of intermediate products, less loss, and, consequently, a decrease in the general cost, as the following figures will show:

	1871.	1872.
Cost of smelting per cwt.* of ore	1 fl. 88.30 kr.	1 fl. 73.98 kr.
Loss in silver	1.274 per cent.	0.853 per cent.
Loss in lead	21.61 per cent.	17.50 per cent.

The following communication upon the cost of smelting and the latest improvements made at Pribram appeared in *The Berg-und Hüttenmännische Zeitung*, 1873, p. 409.

In making use of the iron-reduction process, the yield in lead-matte was 70 per cent. of the ore melted. In 1870, with the roasting and smelting process, combined with the iron-reduction process, the yield was still as high as 42.95 per cent.; in 1871, only 31.32 per cent. was produced; since 1872, with the combined roasting and smelting process

* 1 Austrian cwt. = 56 kilograms = 123 pounds English.

alone, and working an ore containing 55 per cent. lead, the yield in lead-matte was only 10.8 per cent. of the ore smelted.

During the last three years the ores have continually increased, as regards metallurgical treatment, in rebelliousness, the percentage of zinc-sulphide, copper-sulphide, and silicic acid, being continually on the increase. The following three average analyses will show this increase in the ingredients above mentioned. *a*, is an average analysis of the lead ores in December of the year 1870, after the same had been freed from all blendic ore, made by Patera; *b*, average analysis of the ores in the year 1871, made by Mázek; and *c*, average analysis, in the year 1872, made by the same:

	a.	*b.*	*c.*
Lead sulphide	71. 49	68. 11	62. 25
Zinc sulphide	6. 40	8. 01	8. 65
Antimony tersulphide	3. 01	1. 30	1. 50
Argent sulphide	0. 39	0. 38	0. 37
Gold sulphide	....	....	....
Copper protosulphide	Trace.	0. 04	0. 11
Nickel and cobalt	Trace.	Trace.	Trace.
Molybdanium	Trace.	....	....
Iron bisulphide	5. 44	2. 04	1. 97
⅘-iron arsenide	....	0. 51	0. 67
Iron-protoxide carbonate	5. 04	7. 01	9. 17
Magnesia carbonate	....	0. 57	0. 23
Lime carbonate	Trace.	1. 43	2. 32
Manganese protoxide	....	1. 50	0. 14
Baryta carbonate	....	Trace.	Trace.
Gangue, principally quartz	7. 80	....	....
Silicic acid, principally quartz	....	8. 49	11. 92
Alumina	....	0. 37	0. 87
Total	99. 57	99. 76	100. 17

In 1870, instead of the four English roasting-furnaces, three long reverberatory roasting-furnaces were put in operation, and the fourth in the beginning of March, all of which worked well and with a large saving in fuel, as compared with the English furnaces. These furnaces roasted ores containing 55 per cent. galena, so as to free them from all the sulphur contained therein within 2 to 3 per cent., thus causing the good results spoken of above as regards the production of lead-matte. By comparing the former roasting in English and double-roasting furnaces of the year 1869, with that in the long reverberatory roasting-furnaces in 1871 and 1872, we have the following results :

	1869.	1871.	1872.
Workingmen's wages per cwt. of ore ......kreutzer..	8. 27	9. 18	9. 13
Bituminous coal per cwt. of ore ......pounds..	35. 32	25. 44	23. 48
Cost of bituminous coal per cwt. of ore* ......florins..	18. 90	16. 03	15. 50
Cost of roasting per cwt. of ore ......kreutzer..	27. 17	25. 21	24. 63

* The cost of 1 cwt. of bituminous coal in 1869, 1871, and 1872 was 53.5, 63, and 66 kreutzer.

In order, however, to rightly judge of the cost of roasting in both kinds of furnaces, the cost of roasting a cwt. of ore must be carried back

to the wages paid in 1869, and the saving in fuel should be made independent of the favorable price of coal in that year. We then have the following results for the roasting in the long reverberatory furnaces:

	1871.	1872.
	Kreutzer.	*Kreutzer.*
Saving in wages per cwt. of ore	0. 64	1. 61
Saving in bituminous coal	6. 22	7. 81
Total	6. 86	9. 42

Since October, 1871, the lead-matte and furnace-accretions have been roasted in stalls. The new cylindrical blast-furnace with seven tuyeres, (*rundofen,*) with *bosh* and closed top, finished in 1872, allows of from six to seven times greater production than the old blast-furnace with two tuyeres, and saves almost one-third of the fuel necessary for the latter.

The condensing-chambers have proved to be effective. They gave, at the end of the year 1871, 418 cwt.$=20\frac{1800}{2000}$ tons of furnace-fumes, having a value 2,293 fl. 12 kr. in metal, which is about equal to 6 per cent. interest on the cost of building the canal.

The fluxing with lead-matte, lead-slag, and limestone was continued as usual; also the addition of the small percentage of pig-iron, 4 to 5 per cent., for reason of the poverty of the Pribram ores in this metal; but the addition of the iron-slag from puddling-furnace was diminished, by being partially replaced with the cheaper limestone. A mixture of charcoal and coke came into use as fuel, as the use of the latter alone was still too expensive, (1 cwt. coke costing 2 fl., and 1 cwt. charcoal 1 fl. 30 kr.) The pecuniary possibility of the exclusive use of coke will be decided by the seven-tuyered furnace.

For the further manipulation of the silver-lead, a German cupellation-furnace, finished in 1872, and of improved construction, was made use of. In 1871, the Pattinson apparatus was finished, consisting of a melting-kettle and a crystallization-kettle, and in working, by allowing the mother-liquid to flow off, a normal decrease of the percentage of silver in the crystals was effected.

In the manufactory for the manufacture of zinc oxide, finished in 1871, finely crushed blendic ores, containing 17 per cent. zinc, are treated until the residue contains only 20 per cent. of the metal originally contained in the ore.

In order to perfect a systematic manipulation, the following arrangements are to be introduced: A fine brick factory, a refining-furnace for impure lead, zinc-desilverization, the extraction of bismuth from the test of the cupellation-furnace, the resmelting of old lead-slag in cylindrical blast-furnaces, the production of minium, a blast heating-apparatus, and a steam blast-engine, to be used for the cupellation, or during any interruption of the other machinery, &c. The number of workmen employed in 1869 was 285, and in the last three years they averaged 306.

376. The results of extraction in the years 1870 to 1872, as compared to those of 1869, are as follows:

	1869.	1870.	1871.	1872.
1. ROASTING OF THE ORE IN REVERBERATORY FURNACES.				
Consumption of bituminous coal per 100 cwt. ore.......cwt..	35.32	34.04	25.44	23.48
2. SMELTING; A COMBINED ROASTING AND SMELTING PROCESS.				
Consumption of charcoal per 100 cwt. ore ....tons..	83.52	86.05	99.37	71.24
Consumption of coke per 100 cwt. ore ....cwt..	4.34	17.58	3.91	11.32
Consumption of charcoal per 100 cwt. of total charge, including lead-slag.......tons..	26.03	21.25	26.58	26.32
Consumption of coke per 100 cwt. of total charge, including lead-slag.......cwt..	1.35	4.34	1.04	4.16
Consumption of pig-iron per 100 cwt. ore.......cwt..	4.62	3.20	4.18	3.97
Consumption of iron-slag from puddling-furnace per 100 cwt. ore.......wheelbarrows..	19.85	7.00	7.92	10.30
Limestone and lime consumption per 100 cwt. ore.......cwt..	2.85	5.94	9.33	13.65
Consumption of spathic iron-ore per 100 cwt. ore. cwt..	....	....	1.73	3.61
3. IRON-REDUCTION PROCESS.				
Consumption of charcoal per 100 cwt. ore....tons..	54.64	62.01	81.68	....
Consumption of coke per 100 cwt. ore........cwt..	6.83	2.96	....	....
Consumption of charcoal per 100 cwt. of total charge, inclusive of lead-slag.......tons..	18.73	18.05	23.99	....
Consumption of coke per 100 cwt. of total charge, inclusive of lead-slag.......cwt..	2.36	0.86	....	....
Consumption of pig-iron per 100 cwt. ore.....cwt..	16.87	17.73	17.48	....
Consumption of iron-slag from puddling-furnace per 100 cwt. ore.......wheelbarrows..	16.30	2.44	12.63	....
Consumption of limestone per 100 cwt. ore.. cwt..	3.09	6.60	9.70	....
3. CUPELLATION.				
Thirty-inch soft split-wood per 100 cwt. silver-lead.......klafter...	2.48	2.76	2.55	2.66
4. EXPENSES OF PRODUCTION.				
A mint-pound of silver.......	6 fls.	6 fls.	6 fls.	....
Without consideration of the special and general cost of extraction.......	46.68	75.12	20.09	....
With consideration of the special and general costs of extraction.......	....	7 fls., 80 kr.	8 fls., 44 kr.	7 fls., 96 kr.
5. SUMMARY OF METALLIC LOSS.				
Per 100 mint-pounds of the silver contained in the ore.......mint-pounds..	2.612	3.392	1.274	0.853
Per 100 cwt. of lead contained in ore.......cwt...	24.78	24.86	21.61	17.50
Amount of lead-matte remaining.......cwt..	96.15	83.17¾	56.00	541

It must be remembered here that the decrease in the loss of metal in 1872 is still more favorable, as the amount of lead-matte on hand is only 541 cwt., whereas in 1871 the same amounted to 5,600 cwt.; the year 1872, therefore, shows a decrease of 5,059 cwt. The charcoal, in comparison with that of former years, was of poor quality, in consequence of the bad quality of wood used, it being that which had been broken down during the storms of 1868 and 1870, and consisting principally of the top branches of the trees; while, on the other hand, coke stood at an uncommon high price; and, further, because the rapid increase in the price of almost all material, as well as wages, produced an important difference in the cost of extraction.

377. There are at present employed at the Pribram Smelting-Works—

Four stalls and two shaft-furnaces for roasting matte.

Four single-hearthed reverberatory roasting-furnaces, 14.5 meters long and 2.35 wide, with seven working-doors on each side. The capacity is 4,032 kilograms in twenty-four hours. A charge of 1,000 kilograms is drawn every six hours. The roasted ore contains 3 per cent. sulphur. The fumes and gases are conducted through a false hearth in the upper part of the furnace, and from thence through a condensing-canal, 300 meters long, which ends in a chimney 24.648 meters high. Ore is dried by placing it on the top of the furnace before it is charged.

One three-tuyered shaft-furnace, 7.6 meters high and 0.4 meter square at the tuyeres.

Three two-tuyered shaft-furnaces, 7.6 meters high by the tuyeres, 0.3 meter wide, and 0.4 meter deep.

One seven-tuyered shaft-furnace, with cast-iron water-cooling boxes, (Pilz, built in 1871,) 8.2 meters high and 1.6 meters wide at the tuyeres. The shaft widens above the tuyeres and narrows at the top. It is 2 meters wide at the mouth. The ore is charged by means of a mechanical hopper. This furnace gave such good results, that a second one was commenced in 1872 on the same plan, with the addition of an air-heating apparatus and one one-tuyered low shaft-furnace for reducing poor and rich litharge.

Four German cupellation-furnaces; each will contain 6,720 kilograms lead. These furnaces are built in a square, and the silver-lead taken to them, and the products from cupelling are removed by hand-cars, which run on the rails surrounding the furnace. The silver-lead is cupelled without previous concentration. It contains 0.5 per cent. =145 oz. 16 dwt. silver.

One new rectangular cupellation-furnace, which has already been described.

One small cupelling-furnace, with movable hood, for refining the silver from large cupellation-furnace. The silver charged is about $\frac{860}{1000}$ fine; this is refined to $\frac{995}{1000}$.

A Pattinson battery of two kettles, which are used to desilverize the rich litharge. In addition to these, there are the necessary crushing-mills, engines, &c.

378. The Pribram Smelting-Works produced in 1871—

	Kilograms.
Lead	500,976
Litharge	1,627,864
Silver	1,822,688

379. The smelting-works at Kscheutzischer Zeche and Mies exhibited a few samples of ores and products. These were from the former. Blendic galena-ores are roasted in a long reverberatory furnace; the exhibited specimens contained numerous pieces of undecomposed galena and blende, silver-lead, silver, and litharge. From the latter were lead-ores, roasted ores, and silver-lead.

The richest ores from the mining-districts where Kscheutzischer-

Zeche and the Mies smelting-works are situated are sent to Germany for reduction.

380. TYROL.—The Copper and Zinc Smelting-Works of Brixlegg exhibited a plan of the partly erected reduction-works and samples of their ores, among which the following were noteworthy: Copper pyrites, from Schwarz, carrying 13 per cent. copper; bournonite, from Schwarz, with 10 per cent. copper and 0.13 per cent. = 37 oz. 16 dwt. 19 gr. silver. Tetrahedrite, from Madersbacher Kopfel, with 6 per cent. copper and 0.2 per cent. = 56 oz. 6 gr. silver. In addition to these there were raw matte, concentrated matte, rosette-copper, from Brixlegg and Jochberg, sheet-copper, copper-kettles, and tuyeres, and a piece of impure silver, which crystallized upon being allowed to cool on the crystallizing-hearth. The crystals were imperfect octahedrons. The half which was visible was about one-fifth of an inch in diameter. In addition to these was a pyramid about 25 feet high, 5 feet diameter at the bottom, and 2 feet at the top. It was made of wood, upon which were fastened, by means of paste, the different ores treated. On the apex was placed a piece of rose-copper.

381. A model of the newly-erected round six-tuyered shaft-furnace was also exhibited. The smelting-zone is surrounded with iron water-cooling boxes. This is a crucible-furnace with a charging-hopper, cast-iron slag-spout and tap-pots. A system of condensation-chambers are constructed under the floor of the works. The dimensions of this furnace are, 6.3 meters high, 1.5 meters wide at top, 1.2 meters in smelting-zone. Its capacity is 300 centner = 16,800 kilograms in twenty-four hours.

382. These works were first erected in 1450, and were organized and entirely rebuilt in 1870 by the government as a central smelting-works for the copper, silver, and zinc ores extracted from the government mines in the Tyrol and Salzburg, and ores bought from private parties. With this object in view there have already been erected one single-hearthed reverberatory roasting-furnace, 18 meters long and 4 meters wide; one shaft-furnace; one reverberatory furnace, for concentrating copper-matte; one large copper-refining furnace, with a Siemens gas-producer; one cupelling-furnace; one low-shaft furnace, for smelting matte for black copper; a small copper-refining hearth; two copper-hammers; and a copper-rolling mill. At present there are three zinc muffle-furnaces, but it is proposed to build two shaft roasting, four *Gerstenhofer*, and eight muffle-furnaces, viz, three with eighty muffles and five with 136 muffles each, all to be heated with Boëtin's gas-generators; also, a sheet-zinc-rolling mill and a sulphuric-acid manufactory.

383. The ores treated at these works have a varied composition; their contents of copper, silver, lead, and zinc may be seen in the following table, taken from *The Berg- und Hüttenmannische Zeitung*, 1873, p. 94:

	Copper.	Silver.	Lead.	Zinc.
	Per cent.		*Per cent.*	*Per cent.*
Schwarz	5–10	0.080 to 0.10 per cent. = 23 oz. 6 dwt. to 29 oz.	....	....
Kitzbüchel	2–25	....	....	....
Brixlegg	5–16	0.11 to 0.26 per cent. = 31 oz. 20 dwt. to 84 oz. 10 dwt.	30–33	....
Ahrn	1– 5	....	....	....
Klausner mines, pure pyrites	2–20	....	....	....
Copper-ores containing silver	1–14	0.005 to 0.07 per cent. = 1 oz. 9 dwt. to 20 oz. 8 dwt.	....	....
Lead-ores	....	0.005 to 0.13 per cent. = 1 oz. 9 dwt. to 37 oz. 16 dwt.	4–63	....
Blende from Schneeberg	....	....	....	40–63

Ores from Madersbacher Kopfel contain a small amount of nickel and cobalt. In addition to these, raw matte from Kitzhichel, containing 24 per cent. copper, is treated.

384. *Processes.*—Formerly the ores from the mines owned by the government and metallurgical products from Klausen and Kitzhichel were treated according to the complicated Brixlegg-abdarr process, (a process of liquation.) In 1872 the smelting process was simplified, and consists at present of two separate treatments, the copper-process and the lead-process.

385. In the copper process roasted copper ores* are mixed with unroasted ores (both being free from lead and silver) and necessary fluxes, and smelted in a shaft-furnace for raw matte. This is roasted and concentrated in a reverberatory furnace. The concentrated matte is roasted, and then either refined in a copper-refining furnace, whereby block-copper results, or smelted in a low shaft-furnace for black copper, which is refined in a small refining-hearth, whereby rosette-copper is produced.

386. The lead-process consists in mixing the copper-ores containing silver with gold-ores and slimes from Lend and Böckstein, and roasted argentiferous galena. These are smelted in a shaft-furnace, the products of which are speiss, matte, and silver-lead. The silver-lead, containing a small amount of gold, is cupelled. The raw speiss is partly roasted and then concentrated. The matte is roasted and smelted a second time in a shaft-furnace, with roasted lead-ores or oxidized lead-products. The silver-lead from this operation, containing all the gold which was in the matte, is cupelled; the concentrated matte is roasted and smelted in a shaft for argentiferous black copper. The silver is extracted from this by means of sulphuric acid.

387. The zinc and copper produced at these works are partly manufactured into sheet-zinc, sheet-copper, copper-kettles, tuyeres, &c. The Brixlegg Smelting-Works produced annually, copper, 280,000 kilograms; copper articles, kettles, &c., 33,600 kilograms; sheet-copper, 67,200 kilograms; silver, 700 kilograms; gold, 10 kilograms; also, a small quantity of litharge and speiss. It is estimated that upon completion of the zinc-furnaces and the sulphuric-acid manufactory, the annual production of

* *Vide "Ausstellung des K K ackerbauministeriums,"* Wien, 1873, p. 79.

these two articles will be, zinc and sheet-zinc, 2,800,000 kilograms; sulphuric acid, 1,120,000 kilograms; and the value of the total production will be 920,000 florins = $368,000 gold.

388. The Smelting-Works of Jochberg exhibited a few samples of copper-matte, with 22 to 24 per cent. copper and slag. The copper-ores are copper pyrites; the gangue is chiefly slate and quartz. They average 13.5 per cent. copper. These works* produced formerly rosette-copper, but their operations are now confined to the production of raw matte, which is sent to Brixlegg for further treatment. The new round shaft-furnace at the Jochberg works has seven tuyeres, and is 6.3 meters high and 1.3 meters wide in the crucible. The copper from the Jochberg ores is of a superior quality, comparing favorably with the best copper of Russia and Sweden.

389. The Copper-Works of the Mitterberger Gewerkschaft of Mühlbach, in Salzburg, were represented by a small display of ores, copper-matte, and black and refined copper. The ore is composed† chiefly of copper pyrites; the gangue is of a quartzose and spathic nature. An analysis made from an average sample was as follows: Cu. = 11.5 per cent.; S. = 16.1; Fe. = 27.1; Si O_2 = 22.2. Small quantities of alumina, calcite, and magnesia.

390. The smelting process is simple. The ore is roasted in heaps and smelted in shaft-furnaces, with about 10 per cent. slag, from the black-copper smelting, 25 per cent. slag, from the matte-smelting, and 20 per cent. of roasted copper-matte. The resulting copper-matte contains about 25 per cent. copper, and is run from the furnace into water, whereby it is granulated. The granulated matte is roasted and smelted in a low-shaft furnace (to avoid a reduction of iron) with quartz, and slag from the ore-smelting. The concentrated copper-matte contains about 50 per cent. copper. It is crushed, roasted in reverberatory furnaces, and again smelted in a low-blast furnace with quartz and slag from the ore-smelting. The result of this smelting is black copper, which is refined in a copper-refining hearth. The product is rosette-copper. The sweepings are smelted, and form an inferior quality of copper. The nickel-sweepings are granulated and sold.

391. The increased production of ores caused the works to increase the facilities for their reduction. The improvements consist in a round shaft-furnace and a large refining-furnace, which have taken the place of low-blast furnaces and small refining-hearths. The description of the round furnace and the comparison of the new and old shaft furnaces, are from the *Oesterreichische Zeitschrift für Berg und Hüttenwesen*, 1871, No. 22. The communication is by Herrn Superintendent A. Khuen. The furnace is round, widened toward the top, has five wrought-iron water tuyeres, and has the following dimensions: height from bottom of furnace to gas-canal, 14 feet 6 inches; from bottom of fur-

* *Vide "Ausstellung des K K ackerbauministeriums,"* Wien, 1873, p. 89.

† *Vide " Berg- und Huttenmannische Zeitung,"* 1871, p. 285.

nace to tuyeres, 3 feet 6 inches; from the tuyeres to the supporting-ring, 3 feet 9 inches; from the supporting-ring to gas-canal, 7 feet 3 inches; height of charging-hopper, 3 feet 10 inches; diameter at tuyeres, 3 feet; at the mouth, 4 feet; height of tuyeres above the slag-spout, 11 inches. The tuyeres have an opening of $2\frac{1}{12}$ inches in diameter, and are inclined 1 inch. About 700 to 800 cubic feet of air is consumed per minute by the pressure of $\frac{8}{12}$ to $\frac{9}{12}$ inch quicksilver-column. The wall of the smelting-zone, about the tuyeres, is cooled by means of cast-iron pipes through which water is made to circulate. Underneath the tuyeres are cast-iron troughs, into which the water runs from the pipes placed above. The upper shaft is supported by an iron ring, which rests upon three iron pillars. This part of the shaft is formed of sheet-iron lined with fire-brick; it is narrow at the bottom, but widens at the top. A chimney is built over the furnace to catch the sulphureted and arseniureted hydrogen, which escapes from the ore in the charging-hopper. The furnace-gas escapes by a canal attached to the side of the furnace. In the bottom of the canal, near the furnace, is a funnel, which catches the small ore-particles, which are carried off by the draught when finely-crushed ore is smelted. The gas-canal falls at an angle of 45°, and leads to condensing-chambers. The three tuyeres are directed toward the center of the furnace. The blasts from the two front tuyeres cross each other 3 inches in front of the center of the furnace. The object of this is to keep the slag-opening clear and to utilize all of the blast.

A smelting of similar charges in the round and low shaft-furnaces produced in the first matte was 1 to 1.5 per cent. poorer in copper, 0.5 to 1 per cent. in iron, and 2 to 3 per cent. richer in iron than in the latter. The slag from the round furnace was 1 per cent. poorer in iron and 3 per cent. richer in silicic acid than in the low shaft-furnace. The slag from both contained 1 per cent. copper. In spite of the greater contents of the matte in iron, which is eliminated in the following concentration, the advantages of the new furnace are very great, as will be seen by the following comparison: The capacity of the round furnace is greater than that of three low-blast furnaces, with almost 32 per cent. saving in fuel. A large proportion of the ore (55 per cent.) is slime, which causes a large volatilization and irregularities in the working of the furnace. If the slimes are agglutinated with milk of lime, the costs and charge are increased, and the contents of the matte in iron is greater. This inconvenience, it is hoped, will be avoided by producing a smaller amount of slime in the dressing-works, and by smelting with coke instead of charcoal.

392. There is smelted in the round furnace in twenty-four hours a charge of 322 centner,* with a consumption of 42.2 sacks (one sack = 20 cubic feet) charcoal. The products are 120 centner matte and 61 centner fumes; or, calculating after deducting the fumes from 100 centner ore, which is smelted in 10.2 hours with 18.8 sacks charcoal, the products are 51.3 centner matte and 29.9 centner fumes.

* One centner = 110 pounds.

One hundred centner ore are smelted in the low shaft-furnace in thirty-four hours with 27.5 sacks of charcoal, producing 50 centner matte and 2 of fumes. The saving is, therefore, in the round furnace per 100 centner 28.8 hours' time and 8.7 sacks of charcoal.

393. CARINTHIA.—The "Bleiberger Bergswerks-Union," the most important lead mining and smelting corporation in Carinthia, is located at Klagenfurt. It was represented by an interesting display of statistical charts, maps of the mining-district, ores, and products. The products were "*rühr*" and "press" lead, also the following articles from the manufactories owned by this company:

A coil of lead wire and several samples of lead pipe. One piece of lead pipe was coiled so as to resemble a pyramid. It was 371.61 meters long, 10.97 millimeters thick, outside measurement, and weighed 358.96 kilograms. One piece was plated with tin, both inside and out.

A collection of pipes ranging from 6.57 millimeters to 0.126 meter thick, outside measurement. Those under 32.5 millimeters thick were plated on the outside with tin.

Samples of sheet-lead from 0.548 millimeter to 8.776 millimeters thick. One large piece of sheet-lead, 24.65 meters long, 1.896 meters wide, 2.194 millimeters thick, weighed 1,372 kilograms.

In addition to these there were several qualities of red lead, massicot, litharge, and lead-ashes.

394. The Bleiberger Bergwerks-Union own lead-mines near Bleiberg and Miss, in Lower Carinthia; reduction-works in Bleiberg, near Villach, in Miss, and three factories in Villach, viz, one for shot, one for litharge and red lead, and one for pipes, sheet-lead, lead-foil, &c.

Twenty-seven furnaces are in operation at their reduction-works, twenty-five of which are reverberatory furnaces used in the reduction of ore, and two "Rossie's" shaft-furnaces, in which the residue is treated. Wood serves as fuel in the first, and charcoal in the second. The loss amounts to 5.5 per cent. of the lead contained in the ore; part of this remains in the residue and is finally extracted. Real loss, 2.56 per cent.

The galena is free from silver, and occurs in veins, beds, and irregular deposits in limestone. It is accompanied, chiefly, by blende, calamine, cerusite, calcite, and barytes.

395. The lead from Bleiberg is celebrated for its purity, and is known as "Villach lead." Its purity is owing to the absence of large quantities of injurious foreign substances in the ore, and to the peculiar reduction process which it undergoes in small reverberatory furnaces. "Villach lead" contains, according to Streng, the following amount of impurities:

Antimony	0.026
Zinc	0.004
Iron	0.004
Copper	Trace.

The *rühr* lead is used in the manufacture of the different oxides of lead, the press lead in the manufacture of shot.

396. The main object in the Carinthian process is to obtain pure lead and to extract from the ore the greatest amount possible in the reverberatory furnace. To do this the furnace is made small, in order that the temperature may be kept under good control; the charge is therefore necessarily small; the roasting is conducted slowly at a low temperature, and, to avoid the reduction of copper and antimony, the reaction temperature is kept as low as possible. The disadvantages of this method, which are to be considered and compared to the advantages, are the attendant increased cost of fuel, (6.63 centimeters wood to 100 lead is consumed,) labor, and the small quantity of lead produced in a certain time. A Carinthian furnace costs about $120 gold. Double and triple hearth furnaces have been tried, but it was found that they were not suitable for this process. It was desired to roast in the upper and reduce in the lower, but this was impossible, on account of the different durations of these periods. Furthermore, the temperature was difficult to regulate, and the expenses of repairing were large.

The furnace is 3.27 meters long and 1.53 meters wide. The hearth is inclined toward the front, at an angle of 9½°. The lead flows out of the furnace as fast as it is reduced. The hearth is contracted toward the front to a vertical section, presenting the appearance of a bottle. The fire-place is built in the side of the furnace, so that the flames enter the hearth at the back end of the right side; they are then drawn toward the front of the furnace and enter the chimney, which is 0.47 meter in diameter and 6.3 meters high. As wood is used as fuel, it is found desirable to allow the small amount of air necessary for oxidization to enter with the flames.

397. The following short description of the Carinthian process is principally from Percy, Rammelsberg, *Metallurgie des Bleies*, p. 181, 1873:

When the hearth has been heated to a dark-red heat, 168 to 196.5 kilograms ore, containing from 67 to 75 per cent. lead, is thrown in through the working-door and spread over the hearth. The roasting is conducted slowly and carefully, so that the charge neither grows pasty nor adheres to the working-implements. The ore is worked every twenty minutes for about three hours, when the desired quantity of oxide and sulphate of lead will have formed.

The temperature is now raised, in order to cause the oxidized particles to react on the sulphate of lead. The mass is continually worked. Lead flows from the hearth into a cast-iron pot, which is placed in front of the working-door. This period lasts from three and a half to four hours, and is called "*bleirühren*." The lead produced in this period, which is the purest, was formerly termed "*jungfernblei*," (virgin lead,) and was sold as it flowed from the furnace without undergoing any further treatment. It is now called "*rührblei*," and is freed from impurities by liquation before it is sold. The amount of rührblei produced is 56 to 73 kilograms.

The next, or third period, is called "*bleipressen.*" The quantity of the residue, in proportion to the size of the hearth, is so small, that, in order to effect a saving of fuel, the residues from two charges are worked together. If a second residue is ready it is thrown in with the one already in the furnace. Coal-dust is spread over the mass, and while the temperature is raised the coal-dust and residue are well stirred. This period lasts seven to eight hours, during which 67.3 to 101 kilograms lead is produced.

From twenty-one to twenty-three hours are necessary to treat 336.8 kilograms ore. The lead-product is 207.7 to 213.3 kilograms = 95 per cent. of the lead contained in the ore. The residue from the last operation, or dross, is 50.5 to 56 kilograms. It contains 3 per cent., often 9 per cent. lead. This is crushed and dressed until the lead is concentrated to 50 to 60 per cent., when it is either charged with the ore or submitted to the third operation, "pressen." In the latter case *krätz* (dross) lead is produced. As the lead flows slowly from the hearth it becomes mechanically impure; it is therefore returned to the furnace and freed from these impurities by liquation.

398. Production of the "Bleiberger Bergwerks Union" averages—

	Lead.
Bleiberg Smelting-Works	1, 680, 000 kilograms.
Miss Smelting-Works	196, 000 kilograms.

One-sixth of this is extracted from poor stamped ore, three-sixths from jigged ore, and two-sixths from lump ore. The zinc-ores are sent to the zinc-reduction works at Sagor, Ivenec, in Croatia, and Johaannisthal in Krain.

The red-lead and litharge manufactory employs eighteen workingmen and two superintendents. It treats yearly about 616,000 kilograms lead, and produces 617,200 kilograms red lead and litharge, valued at 200,000 florins.

The shot manufactory employs four men and one master. It produces yearly about 403,200 kilograms shot, valued at 130,000 florins.

The sheet lead and pipe manufactory employs nineteen workmen. It treats yearly about 380,800 kilograms, and produces yearly about 352,800 kilograms of manufactured lead articles.

399. The following smaller Carinthian smelting-works were represented: Gustav v. Egger exhibited samples of commercial lead from his works near Paternion in Upper Carinthia. The ore, galena, is associated with calcit and blende. The reduction-process is similar to the Bleiberg process. These works produce yearly from 7,616 to 30,464 kilograms lead. It is expected that the reduction will greatly increase in the next few years.

400. J. Rainer, of Klagenfurt, exhibited geological charts, samples of ores, "*tropf*" and "*stab*" lead from the smelting-works at Bleiberg and Schäffler. In addition to these there were samples of the following manufactured articles: shot, lead ashes, litharge, and several kinds of

white lead. Herr Rainer owns a fourteen twenty-fourth interest in the "Bleiberg und Schmelzwerk Bleiberg," in Feistritz, near Bleiberg; a two-thirds interest in the "Bleiberg und Schmelzwerk Schwarzenbach;" a three-eighths interest in the "Bleibergwerk Rechberg" and Petzen; a one-eighth interest in the "Bleiberg und Schmelzwerk, Miss." The Bleiberg Union owns the other seven-eighths. He owns, in addition to the above, several smaller mines and reduction-works.

401. The smelting process at all these works is the Carinthian process. The production of the smelting-works at Miss has already been given. The production of the Bleiberger Schmelzwerke, founded in 1851, averages 182,616 kilograms lead. The Bleiberg Schäffler und Grafensteiner Alpe, founded in 1809, averages 139,384 kilograms of lead.

402. "Ciprian Struggl's heirs," of Raibl, exhibited geolographical maps of the Raibl district, samples of ores, "*ruhr*" and "press" lead. The ore occurs in beds, in limestone, associated with blende. It is the rule here that when the thickness of the galena-deposit decreases, that of the blende increases, and *vice versa.*

403. Four Carinthian reverberatory furnaces are used for the reduction of the ore; the metallic loss is 8.6 per cent. of the lead contained in the ore.

The following analyses show the amount of foreign substances contained in the Raibl lead:

	Rühr lead.	Press lead.
Antimony	trace.	0.102
Copper	faint trace.	trace.
Sulphur	0.118	0.382
Iron	trace.	trace.
Lead	99.882	99.516

The production of these works averages 258,496 kilograms.

The government works at Raibl have six Carinthian furnaces in operation, and produce annually 338,520 kilograms lead.

404. Franz Puntschart & Sons, of Klagenfurt, exhibited several samples of white lead. The purity of the Carinthian lead, together with the peculiar process employed in the manufacturing of white lead, (which originates in the Dutch method,) has enabled the Carinthian manufacturers to produce an excellent article, which is greatly sought for and exported to England, France, America, Belgium, Holland, Russia, Germany, Italy, and the oriental countries. The yearly production averages 168,000 kilograms.

405. The white-lead manufactory of this firm was erected in the year 1800. According to the process* then in vogue, thin sheet-lead was rolled up, forming a spiral pyramid; this was placed in clay pots, the necessary amount of acetic acid added, and, in order to secure the heat for the reaction, the pots were buried in horse-manure.

* The data concerning this firm were obtained from the "*Special Katalog der Collectiv-Ausstellung im Pavillon der Kärntner'schen Montan Industriellen.*" Klagenfurt, 1873.

406. This method was greatly improved, about the year 1835, by the erection of lead-chambers. In these, thin sheet-lead was hung for oxidization. The floor of the lead-chambers contained numerous holes; under each hole a pot containing acetic acid (produced from raisins) was placed, and the acetic-acid fumes were driven into the lead-chambers by a simple and ingenious contrivance. The acetic-acid pots under each chamber were brought into communication with two copper kettles, under which fire was maintained in such a manner that the cold acetic acid entered the copper kettles through pipes connecting the kettle with the lower part of the pots, and upon being heated escaped through pipes from the top of the kettle into the pots containing the cold acetic acid. The latter soon became heated, and, volatilizing, entered the lead-chambers. By this process it is possible to produce greater quantities of white lead, which are perfectly amorphous.

407. In the year 1872 the manufactory was bought by Herr Franz Puntschart, who immediately made important improvements on the old method. These consisted in the introduction of purified pyroligneous acid, which is cheaper than acetic acid and produces better white lead, and in the discovery that white lead dried by air is better than that dried by artificial heat. To effect this he erected extensive air-drying chambers. This firm produces annually 672,000 kilograms white lead.

408. Franz P. Herbert exhibited also several samples of white lead. He owns manufactories in Klagenfurt and Wolfsberg, Carinthia, and in Lavis, in the Southern Tyrol.

The manufactory in Klagenfurt was founded in 1760. The process is the same as that of Herr Puntschart.

409. STYRIA.—The Ludwigs Kuschelischen Hütte, near Peggan, was represented by lead-ores, galena, silver-lead, enriched and commercial lead and silver.

410. The ores that are treated at the Ludwig Smelting-Works are argentiferous galena, associated with blende, iron pyrites, baryte, and quartz. The blende is so intimately mixed with the galena that it is only to be eliminated by dressing to 8 per cent. The smelting is conducted according to the former Harz iron-reduction process. The unroasted ore (slime) is smelted with iron tap-cinder in a shaft-furnace 21 feet high.

411. The silver-lead contains 0.08 per cent. = 26 oz. 6 dwt. 12 gr. silver. It is desilverized by means of zinc. For this purpose there is a battery of three kettles; the two outer ones for desilverizing the lead, and the middle one for liquating the lead from the zinc-scum and for the further treatment of the zinc-scum. The silver-lead is melted in the two outside kettles, and, after the removal of the dross, (abzug,) zinc is added to the molten liquid for about an hour; the temperature is then decreased till the zinc-scum forms, which is ladled into the middle kettle. The bath is heated, stirred, and cooled, when the scum formed is also ladled into the middle kettle. Two more portions of zinc are now added

and the former manipulations repeated. The total consumption of zinc is 0.7 per cent. of the silver-lead treated. The silver-lead assays, after the removal of the first zinc-scum, 0.02 per cent. = 5 oz. 16 dwt. 14 gr. silver; after the removal of the second, 0.003 per cent. = 17 dwt. 11 gr. silver; and after the removal of the third, 0.0005 per cent. = 2 dwt. 21 gr. silver. The poor lead is dezinckified by means of steam. The remaining lead is about 80 per cent. of the silver-lead charged, and is a superior quality. Analysis made for zinc and iron failed to discover a trace of the former, and the latter was only found in unweighable quantities. This report failed to state how the lead from liquated zinc-scum, as well as the latter, (zinkstaub,) was treated. But it is probable that the former is treated with a second and third zinc charge, and the latter is cupelled. This conclusion is drawn from the fact that the works have no distilling-apparatus or shaft-furnace for the treatment of rich oxides should such be produced. In addition to the desilverization-battery, there are also a shaft-furnace and one cupelling-furnace in operation at these works.

412. The annual production is—

	Kilograms.
Lead	288,000
Silver	2,240

413. KRAIN.—The "Ludwigs-Kuschelzink Hütte," of Johannisthal, exhibited zinc-ores (calamine and blende) and different grades of zinc. An analysis, accompanying a sample of zinc, showed the amount of impurities contained in this metal to be—

	Per cent.
Zinc	99.92
Lead	0.02
Iron	0.06
	100.00

The sample exhibited showed silver-white cystal surfaces. Although this is unusually pure zinc, it is probable that the analysis sent to the Exposition was not an average analysis of the best grade zinc. I give an analysis, made at the imperial assay-office in Vienna, of the Johannisthal zinc:

	Per cent.
Zinc	99.404
Lead	0.563
Cadmium	0.019
Iron	0.014
	100.000

414. The same works also exhibited a model of "Kuschel and Hinterhuber's" rotary roasting-furnace, and blende treated therein from two roasting periods. The unroasted ore contains 55 per cent. zinc; the

half-roasted ore, 60.4 per cent. zinc; and the dead-roasted ore, 67.7 per cent. zinc. The construction of this furnace was made public by Herrn H. Hinterhuber in 1871. I reproduce his description:

The furnace presents the appearance of a German cupellation-hearth. Its main features are a horizontal revolving hearth, made of fire-clay, and stationary rakes. The rakes, which are not attacked by sulphur, &c., or easily destroyed by fire, give this furnace a decided advantage over those of Parkes, Brunton, and Gibb and Gelstharp. The hearth consists of an iron shell, in which is carefully stamped a mixture of unburnt fire-clay and dust of fire-bricks, (*chamotte.*) It is 12 feet in diameter and revolvable. Covering the hearth is a strong arch 12 inches thick; in the center it is 17 inches above the hearth, and on the periphery, 7 inches. Through the center of the arch pass 10 hollow three-cornered teeth of fire-clay, placed in a row; these last on an average two and one-half months. The points of the teeth nearly touch the surface of the hearth. There is a charging-funnel over these teeth, the charge passing through the teeth or rakes on to the hearth, after the plugs, which keep them closed, have been withdrawn. In order that the resulting roasted product should be of a uniform nature, it is of importance that the surface of the hearth should be perfectly even, and that the teeth of the rake be made of good fire-proof material which will not shrink or become distorted. The hearth-material is covered with large fire-bricks well joined and plastered. The points of the five teeth on one side point in the opposite direction from those on the other side, thus effecting, at one and the same time, a raking and a turning of the charge. On one side of the hearth there are two ordinary fire-places or gas-generators, and opposite the same, on the other side, thirteen flues, which conduct the gases of combustion into a semicircular collecting-chamber common to them all, and from here the gases pass off into a chimney. The draught is regulated by apertures situated in the outer wall of the collecting-chamber corresponding to the flues, which may be opened or closed. The steam is conducted into the furnace through two nozzles situated between the two fire-places. Though partially contrary to former experience and the statements of Plattner, the introduction of steam into the furnace has proved to be very effective in removing sulphur and arsenic; and also in operations of calcination for the removing of carbonic acid. It also opposes the evolving of fumes during the first period of the roasting operation. At the Johannisthaler Zinkhütte the roasting products, rich in sulphur, could be roasted dead in from 1 to 2 hours sooner, when steam was employed, than when the operation was conducted without its employment. The amount of zinc produced was also 2 per cent. greater. The reason why Plattner obtained less satisfactory results may have been the fact that he endeavored to decompose the metallic sulphides with steam by exclusion of air. The roasting charge is allowed to fall upon the hearth of the sufficiently-heated furnace by

opening the hollow rake-teeth. At first, where it is only intended to expel the hydroscopic moisture of the charge, the draught is feeble and regulated by the openings in the collecting-chamber for the gases, in order to prevent the carrying off of small particles of ore. The hearth is also made to revolve slowly. If the charge is very moist, the raking-apparatus is raised at first so that it will not come in contact with the charge, and is not lowered until all the moisture is expelled from the ore. Steam is employed both during the first period and the dead-roasting period. When metallic sulphides are being treated, it not only causes a more complete desulphurization, but also diminishes the time necessary for conducting the operation. Steam is only employed during the first period in merely heating and calcination operations, it opposing the carrying off of small particles of the charge by the draught in the furnace, and also conducing to the ejection of carbonic acid. After the completion of the operation a slide discharging-apparatus is lowered down upon the hearth through a radial slit in the furnace-arch, which brushes the roasted charge through four apertures situated on the periphery on the hearth into a space under the furnace.

415. The following results were obtained at the Johannisthaler Zinkhütte in treating zinc-blende, containing 43 to 46 per cent. zinc and 22 to 25 per cent. sulphur, in the mechanical roasting-furnace, (A,) and in a Mansfeld double-hearth long reverberatory roasting-furnace, (B :)

	A.	B.
Amount roasted in twenty-four hours	21 to 42 cwt.	20 to 24 cwt.
Time necessary in roasting, per charge	18 to 22 hours	12 to 15 hours.
Production of zinc from roasted blende	35 to 39 per cent	33 to 36 per cent.
Consumption of coal in twenty-four hours	24. 6 cwt	24. 6 cwt.
Wages for twenty-four hours	1. 4 florins	2. 5 florins.

The above calculated per ton of raw ore roasted would be:

	A.	B.
Consumption of coal	58. 6 to 117 pounds	103 to 113 pounds.
Wages	3. 3 to 6. 6 kreutzers	10. 4 to 12. 5 krs.
Increase of zinc production	2 to 3 per cent	

The fluctuation in the amounts roasted within the same time is caused by the varying size of the ore-grains. By proper treatment of the ore-charge, 42 cwt. of blende can be roasted on an average in twenty-four hours, with a saving of 43 per cent. in fuel and 68 per cent. in wages, as compared with the results obtained by the long reverberatory furnace. From 30 to 40 cwt. of crushed or washed calamine carrying zinc-blende were treated in the mechanical roasting-furnace in twenty-four hours, and in the long reverberatory furnace only 24 cwt.

The furnace has been in use over three years at the works named. The mechanical furnaces have many advantages over most other roast-

ing-apparatus. The most important are saving of fuel and wages, and the maintenance of a well-regulated temperature. The roasting is said to be very good. They also are adapted to chloridizing roasting. The costs of repairs were not obtained, but, as they must be large, they should not be omitted when this class of furnace is taken into consideration.

416. These zinc-works at Johannisthal were erected in 1860. They received the greater part of their ores at first from Upper Styria and Northern Carinthia, but the mines near the smelting-works have lately been more fully developed, and although ore from the above localities are still treated, the reduction-works are not dependent on them. There are at present five Mansfeld reverberatory roasting-furnaces with two hearths, one Kuschiel and Hinterhuber's roasting-furnace, ten Belgian distillery-furnaces, and one Silesian furnace with a gas-generator. The annual production of zinc is 573,048 kilograms.

417. BUKOWINA.—The Copper-Works of Pozoritta in Bukowina, belonging to the "Griechisch-Orientalischen Religionsfond in der Bukowina," were well represented. In this display the following were considered noteworthy:

A statistical map; a black line denoted the quantity of copper produced in different years, and a red line showed the amount of money received for the above copper. This made a comparison of the price of copper in the different years with the quantity produced.

A series of copper-ores containing from 3 to 16 per cent. copper showed the principal mineral to be copper pyrites; the gangue is quartzose. A systematic collection of metallurgical productions presented an interesting insight into the copper process.

1. Copper-matte from ore-smelting contained 14 per cent. copper This is roasted in heaps nine or ten times and smelted for black copper.
2. Slag, from smelting of ore for matte. This is either made into building-stone or thrown on the slag-dump.
3. Black copper, from smelting of roasted matte. This is refined.
4. Slag, from smelting of matte for black copper; contained 0.5 to 8 per cent. copper. It is smelted with roasted ore.
5. Cakes of refined copper; contained 90 per cent. copper; this is again refined in a small furnace.
6. Copper sand, produced toward the end of the refining process.
7. Copper ingots, from second refining; they are made into kettles.
8. Copper bars, from second refining; they are articles of commerce.

418. There are at Pozoritta two roasting-stalls, three shaft-furnaces, (two for ore and one for matte-smelting,) two refining-furnaces, and five copper-hammers. As the copper-production is yearly decreasing, it is proposed to change one of the ore shaft-furnaces into an iron-smelting furnace. These works produced, in 1871, from ores and old copper, 46,022 kilograms copper.

419. HUNGARY.—A very interesting exhibit was made by the Royal

Hungarian Mint of different coins, dies, and the various utensils employed in coining.

420. There was also a new process of extracting silver from silver copper alloys, illustrated by specimens of the products occurring in the different manipulations. This process was invented and carried out by the mint warden, Herr Johann Cimeg. It consists in a series of smeltings of the silver-copper alloy, in crucible furnaces, with a quantity of sulphur sufficient to unite with a certain percentage of the copper, whereby copper, having a greater affinity for sulphur than for silver, forms a matte, having a smaller proportion of the silver than was contained in the alloy. While the silver is, by degrees, concentrated in the alloy, the copper-matte, being of a less specific gravity, rises to the top and is drawn off. The silver-copper alloy remains behind, and is resmelted with copper-matte, or with an alloy and sulphur. The exhibited specimens illustrated the process, and were taken from the different meltings:

No. I. Copper-matte, assaying 11.1 per cent. and silver-copper alloy with 45.7 per cent., from melting in crucible 400 pounds* six-kreutzer pieces and 353 pounds matte assaying 14.2 per cent. Ag. from a former operation. Result, 308 pounds matte.

No. II. Matte, 11.3 per cent. Ag. alloy and 46.2 per cent. Ag., from smelting the alloy remaining from No. I in crucible with 347 pounds matte, assaying 14.2 to 14.6 per cent. Ag., from a former smelting.

No. III. Matte, 13.1 per cent. Ag. alloy and 48 per cent. Ag., from melting alloy remaining with No. II with 359 pounds matte assaying 14.6 to 15.9 per cent. Ag. Result, 312 pounds matte.

No. IV. Matte, 13.3 per cent. Ag. alloy and 51.1 per cent. Ag., from melting alloy remaining from No. III with 307 pounds matte assaying 17.9 to 18 per cent. Ag. Result, 330 pounds matte.

No. V. Matte, 13.3 per cent. Ag. alloy and 52 per cent. Ag., from melting alloy remaining from No. IV with 346 pounds matte assaying 18.5 to 18.7 per cent. Ag. Result, 313 pounds matte.

No. VI. Matte, 13.5 per cent. Ag. alloy and 52.5 per cent. Ag., from melting alloy remaining from No. V with 335 pounds matte assaying 18.7 to 18.9 per cent. Ag. Result, 321 pounds matte.

No. VII. Matte, 13.7 per cent. Ag. alloy and 54.5 per cent. Ag., from melting alloy remaining from No. VI with 289 pounds matte assaying 18.9 to 25.2 per cent. Ag. Result, 261 pounds matte.

No. VIII. Matte, 15.8 per cent. Ag. alloy and 60.6 per cent. Ag., from melting alloy remaining from No. VII with 100 pounds six-kreutzer pieces, 17 pounds sulphur, and 226 pounds matte assaying 25 to 34 per cent. Ag. Result, 294 pounds matte.

No. IX. Matte, 16.7 per cent. Ag. alloy and 66.5 per cent. Ag., from melting alloy remaining from No. VIII with 300 pounds six-kreutzer

* 1 Austrian cwt. = 100 pounds = 56 kilograms = 123.2 pounds English avoirdupois.

pieces and 57 pounds sulphur. Result, 273 pounds matte and 200 pounds alloy, taken out and granulated.

No. X. Matte, 18.7 per cent. Ag. alloy and 71.9 per cent. Ag., from melting alloy remaining from No. IX with 316 pounds six-kreutzer pieces and 68 pounds sulphur. Result, 328 pounds matte.

No. XI. Matte, 19.5 per cent. Ag. alloy and 75.6 per cent. Ag., from melting alloy remaining from No. X with 300 pounds six-kreutzer pieces and 51 pounds sulphur. Result, 187 pounds matte.

No. XII. Matte, 19.8 per cent. Ag. alloy and 79 per cent. Ag., from melting alloy remaining from No. XI with 236 pounds six-kreutzer pieces and 43 pounds sulphur. Result, 216 pounds matte.

No. XIII. Matte, 25.8 per cent. Ag. alloy and 83.4 per cent. Ag., from melting alloys remaining from No. XII with the 200 pounds granulated alloy from No. IX (assaying 66.5 per cent. Ag.) and 35 pounds sulphur. Result, 219 pounds matte and 200 pounds of alloy, taken out and granulated.

No. XIV. Matte, 54.7 per cent. Ag. alloy and 89.4 per cent. Ag., from melting alloy remaining from No. XIII with 200 pounds granulated alloy from No. XIII (assaying 83.4 per cent. Ag.) and 35 pounds sulphur. Result, 220 pounds matte and 553 pounds silver-copper alloy, which is the final product.

The silver-copper alloy from No. XIV is either melted in charges of 1,000 pounds, with saltpeter, in cast-iron kettles, and, after the impurities have been removed, cast in molds, or copper is added until it assays 90 per cent. Ag. and 10 per cent. Cu., which is the alloy used for the Hungarian-Austrian silver guilder.

Matte assaying over 14 per cent. Ag. is remelted in the operation following. But matte assaying less than 14 per cent. Ag. is crushed, roasted, and desilverized by means of sulphuric acid.

421. This process is adapted to the extraction of silver from copper alloys where the percentage of silver is so great that it is made desirable to obtain a greater part of it in a short time. The silver remaining in the copper-matte is extracted by a humid process. In the above instance a small part of the matte was sent to Tajova, where the modified Augustins method is practiced. The greater part, however, was sold to the Freiberg metallurgical works for treatment with sulphuric acid.

Herr Cimeg stated to the author that this process had given unqualified satisfaction, as conducted at the mint in Kremnitz. The amount of six-kreutzer pieces treated was 140,040 pounds in 19 working-weeks, with a consumption of 25,312 pounds Sicilian sulphur. They assayed 43 per cent. of silver and 57 per cent. of copper. 77.22 per cent. of the silver contained in the coin was extracted as an alloy; 21.38 per cent. remained in 1,016 cwt. of copper-matte. The loss in silver was 1.4 per cent. The treatment of so large a quantity of silver coin was caused by the Austrian-Hungarian government issuing new coin of a different standard.

422. The Lower Hungarian smelting-works at Schemnitz, Kremnitz, Tarnowitz, Neusohl, were represented by a collection of their ores; intermediate and final products, consisting in silver, copper, and lead ores, slag and matte from different smeltings; litharge; a piece of cupellation-hearth so strongly impregnated with litharge that it was scarcely to be distinguished from the latter; lead; and fine silver.

423. A systematic collection of ores and metallurgical products were exhibited from the smelting-works at Tajova, illustrating the smelting and silver extraction as conducted at that place. It consisted in copper (gelferz) and argentiferous copper-ores, matte, black copper, refined copper, residue from the silver extraction, cement silver, and refined silver.

424. METALLURGICAL PROCESSES OF LOWER HUNGARY.—When the author was in Schemnitz, in August, 1873, collecting data for this report, he was shown by Herrn Josef Wagner, royal assayer in Schemnitz, an unusually excellent description of the Lower Hungarian smelting processes, which is here given, with some slight modifications. This communication appeared afterward in the *Oesterreichische Zeitschrift für Berg und Hüttenwesen* in September and October, 1873.

In this communication all metallurgical processes are spoken of that have existed up to the year 1873 in the Lower Hungarian mining-districts; what success they have met with, and through what changes, modifications, and new improvements the same have passed, and what may be expected of them.

Mining and smelting in the Lower Hungarian district probably had its commencement in the thirteenth century, when a large number of miners emigrated from Germany and settled in those localities where indications of ore-deposits were visible. Mining has been very successfully conducted, but within the last few years the production of silver, lead, and copper has somewhat decreased.

425. The principal object of all the metallurgical establishments is the utilization of the auriferous-argentiferous lead and silver ores and metallurgical products, argentiferous copper-ore, (tetrahedrite,) and non-argentiferous copper-ores, (*gelferze*.) The Lower Hungarian metallurgical process is consequently separated into two chief branches, viz

A. Silver and lead extraction.

B. Copper extraction, combined with the extraction of silver by means of the humid process.

426. For the utilization of the above-named metallurgical products and ores amounting to 180,990 cwt* = 9,049½ tons, there were up to the year 1873 the following metallurgical establishments:

1. The Schemnitz Hütte, divided into the upper and lower works.

a. There are two blast-furnaces at the upper works, 28 feet high, having the shape of a trapezium viewed in horizontal section; two ordinary double-hearth reverberatory roasting-furnaces, of the Hungarian

* 1 cwt = 123.2 pounds English avoirdupois.

pattern, and an establishment for the extraction of silver, according to Ziervogel's process, and the extraction of gold, according to Plattner's process. Since the year 1864 this silver and gold extraction establishment has been out of use.

b. In the lower works there are two low blast-furnaces, 22 feet high, having the shape of a trapezium viewed in horizontal section, a cupellation-furnace, a combined lead liquation and refining furnace, a Pattinson battery, consisting of two kettles, one higher than the other, the upper communicating with the lower by means of an iron pipe attached to the bottom of the upper, and two double-hearthed reverberatory roasting-furnaces, (*fortschaufelungsoefen.*) These were completed in 1873, but had not been used up to the year 1874. The annual production is equal to 8,336.057 mint-pounds of silver, 105.476 mint-pounds of gold, 1,436 cwt. (Vienna) commercial lead, and 1,649 cwt. of red and green commercial litharge.*

427. 2. The Zsarnoviczer Hütte has two high blast-furnaces and two low, all having the shape of a trapezium viewed in horizontal section, four roasting-furnaces, two German cupellation-furnaces, and one lead liquation and refining furnace. The annual production amounts to 8,336.057 mint-pounds of silver, 149.871 mint-pounds of gold, 1,815 cwt. of lead, and 2,740 cwt. of red and green commercial litharge.

428. 3. The Neusohler Hütte has three high and two low blast-furnaces, four roasting-furnaces, a cupellation-furnace, and one lead liquation and refining furnace. The annual production amounts to 6,650.629 mint-pounds of silver, 150.264 mint-pounds of gold, 600 cwt. lead, and 2,332 cwt. red and green commercial litharge.

429. 4. The Kremnitzer Hütte. These work only smelt ore, and have two high blast-furnaces. The raw matte produced from these two furnaces, amounting to 22,250 cwt., is desilverized at the Neusohler and partly at the Zsarnoviczer Hütte.

430. 5. The Tajovaer Hütte, with the incorporated Hütte at Altgebirg, have for their object the utilization of the copper-ores from the Aeraerial (government) and private mines, and the copper-matte produced at the Lower Hungarian lead and silver smelting works. The annual production amounts to about 900 mint-pounds of silver, and 2,868 cwt. of copper.

431. 6. The Mutual St. Michaelstollner Dillner Hütte has two low blast-furnaces, two roasting-furnaces, a cupellation-furnace and liquation-hearth combined, with a lead-refining furnace. This establishment only works company ores from St. Michaelstollner. The annual production amounts to 1,050 mint-pounds of silver, 70 mint-pounds of gold, and 3,400 cwt. of lead.

All of these smelting-works belong to the government, with the ex-

*All the figures that occur in this paper are the average figures of three years, the years 1868, 1869, and 1870. A Vienna centner (cwt.) = 112 zoll pounds = 56 kilograms.

ception of the Dillner Hütte, but in all of them more or less ores from private company mines are smelted.

The manner in which the mines are re-imbursed for their ores by the smelting-works will be spoken of later.

432. A. LEAD AND SILVER SMELTING.—The lead and silver smelting process is very nearly identical at all the various works, as far as the roasting of intermediate lead products is concerned. The following are the principal steps of the process:

I. The ore smelting for matte.
II. Reichverbleiung, with its preliminary and finishing work.
III. Cupellation.
IV. Liquation.

433. I.—*Ore-smelting for matte.*—The poorest auriferous-argentiferous ores containing no lead are smelted for matte. They are as follows, viz:

a. Quartzose ores containing less than 0.070 per cent. = 20 oz. 8 dwt. 4.80 gr. of auriferous silver, but capable of producing 40 to 80 per cent. of matte.

b. Dressed or concentrated silver-ores containing 0.07 per cent. = 20 oz. 8 dwt. 4.8 gr. auriferous silver.

c. Undressed ores containing from 0.07 to 0.14 per cent. = 20 oz. 8 dwt. 4.8 gr. to 40.5 oz. auriferous silver.

d. Pyritous ores, with or without auriferous silver, but capable of producing at least 60 per cent. of matte.

e. Furnace-dross, from same operation.

The object of this manipulation is the slagging off of the worthless gangue matter, and the concentration of the metals in a matte. After the years 1868, 1869, and 1870, there was smelted annually, at all the smelting-works, about 56,320 cwt. of raw ore.

A smelting-charge generally consisted of 100 cwt. dressed and undressed ore, capable of producing 45 per cent. of matte; 4 to 6 cwt. of furnace-dross from the same operation; 100 to 120 cwt. slag from the Reichverbleiung, and 15 to 20 cwt. limestone.

The following were the products therefrom:

a. Raw matte, containing 0.166 to 0.260 per cent. = 48 oz. 7 dwt. to 81 oz. 13 dwt. of auriferous silver. This goes to the Reichverbleiung;

b. Furnace-dross which passes through the same manipulation;

c. Slag.

The percentage of auriferous silver was:

	Per cent.
In matte	97
In furnace-dross	1
Total	98

Loss, 2 per cent.

The amount put through in twenty-four hours, in one furnace, 70 or 90 cwt.

The consumption of fuel for every 100 cwt. of ore, dressed and undressed, amounts to 144 mass, (one mass is equal to 6.4 cubic feet.)

The total cost of smelting 100 cwt. of ore amounts to:

	Fl.	Kr.
General cost and cost of manipulation	96	90
Cost of fuel	54	90
Superintendence	8	90
Total	160	70

The average cost of smelting 1 cwt. of ore for matte amounts to 90.7 kreutzer.

434. *II.—Reichverbleiung.*—The following ores and metallurgical products are treated in this manipulation:

a. Lead-ores containing from 0.03 to 0.1 per cent.=8 oz. 14 dwt. 19.2 gr. to 29 oz. 2 dwt. of auriferous silver, and from 40 per cent. to 60 per cent. lead;

b. Lead-slimes, containing from 0.025 to 0.1 per cent.=7 oz. 6 dwt. to 29 oz. 2 dwt. of auriferous silver, and from 20 per cent. to 60 per cent. lead;

c. Lead-copper ores and rich pyritous slimes from the dressing of the lead-ores;

d. Ores and slimes, containing from 0.14 per cent.=40 oz. 16 dwt. auriferous silver, up to the highest amount;

e. Raw matte from the ore-smelting for matte (I);

f. Furnace-products from the same manipulation, viz, lead-matte, sweepings, furnace-fumes, and lead-slag;

g. Products from the cupellation and liquation manipulation.

The following chemical analysis will serve to show the chemical constitution of the above ores:

No.	Mining company.	SiO_3	Al_2O_3	CaO	MgO	Fe	Zn	MnO	Cu
	SILVER-ORES.								
1	Neu Antoni	88.640	2.767	1.066	0.158	1.690	0.112	0.093	0.091
2	Carlschachter	60.190	6.476	3.083	1.003	3.928	0.361	9.256	0.151
3	Christina	59.855	7.712	4.380	1.592	3.334	0.415	6.682	0.282
4	Siglisberger	47.746	8.211	2.083	2.150	7.318	2.327	6.031	0.793
5	Franz-Schachter	32.910	17.011	10.740	1.665	5.838	0.305	6.195	0.055
6	Schopferstollner	79.646	1.214	7.694	0.442	2.123	....	....	....
	LEAD ORES AND SLIMES.								
7	Pacherstollner	19.370	2.200	Trace.	0.170	2.340	10.210	0.170	1.280
8	Michaelistollner	20.400	2.128	0.174	0.255	4.425	11.644	....	1.450
9	Pacherst. Schlich	4.680	1.280	0.190	Trace.	9.850	6.190	Trace.	1.290

Chemical Analysis—Continued.

No.	Mining company.	Pb	Au Ag	Sb	S	Mg	Combined with $Si\,O_3$ Ca	Combined with $Si\,O_3$ Co_2	O. HO and loss.
	SILVER-ORES.								
1	Neu Antoni	0. 328	0. 254	0. 087	2. 142	0. 300	0. 120	1. 068	1. 084
2	Carlschachter	1. 195	0. 207	Trace	4. 475			8. 375	1. 300
3	Christina	0. 672	0. 385	..do	3. 945	0. 315	0. 523	9. 250	0. 658
4	Siglisberger	2. 918	0. 370	..do	9. 126			7. 833	3. 094
5	Franz-Schachter	0. 300	0. 255	..do	5. 965	0. 345	0. 600	14. 400	3. 360
6	Schopferstollner		0. 539	0. 160	1. 379			6. 542	0. 266
	LEAD ORES AND SLIMES.								
7	Pacherstollner	48. 100	0. 040				1. 360		1. 310
8	Michaelistollner		0. 048	Trace.			$S\,O_3$		
9	Pacherst. Schlich	52. 320	0. 050	0. 050			1. 360	0. 150	1. 800

435. The "Reichverbleiung" consists in the following manipulations:

1. Roasting, as preliminary manipulation.
2. "Reichverblei" smelting, as chief manipulation.
3. Matte-smelting.
4. Matte-matte smelting, (Lech-Leechschmelzen,) final manipulation.

436. 1. *Roasting. a. Roasting in reverberatory furnaces.*—The lead-ores to be roasted are so mixed with richer pyritous-lead slimes and argentiferous slimes that the average percentage in lead will amount to between 30 and 45 per cent. Such a roasting-charge weighs about 1,000 cwt., and is called the lead-wasting dump.

Analysis of wasting-dump at the Dillner Hütte No. 10.

$Si\,O_3$	17. 870
$Al_2\,O_3$	1. 842
Ca O	2. 680
Mg O	0. 320
Fe	15. 187
Zn	9. 429
Cu	1. 099
Pb	33. 332
Sb	0. 042
S	16. 770
Au+Ag	0. 029

The method of roasting is different at the various works. At the Schemnitzer Hütte slag-roasting is in vogue, at the Zsarnoviczer & Neusohler Hütte dust-roasting, (roasting without agglomerating,) and at the Mutual Dillner Hütte the agglomeration-roasting is made use of. It remains to be said that by the use of the slag-roasting the loss in lead and the consumption of fuel are greater than by the other methods, but, on the other hand, has the advantage that it allows of a better desulphurization and preparation of the roasting-charge.

The result of desulphurization by the different methods of roasting is as follows:

Slag-roasting, (roasting until the charge is well melted,) 2 per cent.

sulphur remains; agglomerating roasting, $3\frac{1}{2}$ per cent. sulphur remains; dust-roasting, (roasting without fusing or agglomerating,) 5 per cent. sulphur remains.

According to analysis by the Gewerkschaftlicher Central-Probirgadens, the raw-lead roasting-heap (Dillner Hütte) contains 16.770 per cent. S.; after preliminary roasting it contains 11.680 per cent. S.; after dead-roasting it contains 3.630 per cent. S.

The roasting is conducted at all the works in Hungarian "Fortschaufelungsofen" (long reverberatory roasting-furnaces) with double hearth. About 40 cwt. of the roasting-heap is put through in every twenty-four hours.

The consumption of fuel per 100 cwt. is as follows:

In the slag-roasting	$2\frac{1}{2}$ to $3\frac{1}{2}$ klafters of 3-foot wood.
In the agglomerating roasting	2 to 3 klafters of 3-foot wood.
In the dust-roasting	$1\frac{3}{4}$ to 2 klafters of 3-foot wood.

The average cost of roasting 100 cwt. of charge by the agglomerating roasting method is—

	Fl.	Kr.
Cost of fuel, $2\frac{1}{4}$ klafters wood, at 6 florins 15 kreutzer	15	18. 75
Wages, $5\frac{1}{2}$ shifts, at 1 florin 20 kreutzer	6	60. 00
Repair of tools for $5\frac{1}{2}$ shifts, at $3\frac{3}{4}$ kreutzer	0	19. 50
Total	21	98. 25

The actual cost of roasting, exclusive of superintendence, is equal to about 21.98 kreutzer per cwt.

b. Roasting in free heaps.—Raw matte, lead-matte, copper-matte, and furnace-dross are roasted in this manner.

The expenses per 100 cwt. are—

	Fl.	Kr.
For stamping 100 cwt., at 1 kreutzer	1	0. 00
For laying over 100 cwt., at $\frac{3}{4}$ kreutzer	0	75. 00
For fuel, $\frac{1}{6}$ klafter wood, at 6 florins 75 kreutzer	1	12. 00
For arranging the roasting-floor, one shift	0	50. 00
Total	3	37. 00

437. 2. "*Reichverbleischmelzen.*"—This, the principal manipulation of the silver-smelting works, beneficiates the richer silver-ores and slimes with roasted lead-ore, roasted raw matte, cupellation-products, and dross. The object of this manipulation is the slagging-off of the worthless gangue matter and a concentration of the gold and silver in the lead. As is to be seen from the foregoing analyses, the silicic acid is the principal slag-forming ingredient. The character of the ores is acid, that is to say, there is a superabundance of silicic acid and a lack of bases. Furthermore, all the ores, especially the lead-ores, carry a large percentage of zinc. It is well known how disadvantageous to lead-smelting processes this metal is. Now, in order not to supply the lack of bases with worthless fluxes, and also to make the zinc in smelting as little troublesome as

possible, the ore-charge is fluxed with the roasted matte that contains a large percentage of iron and some gold and silver from the government works. This not only supplies the place of the failing bases, but also acts as a solvent on the zinc. The fusibility of the charge depends upon the amount of roasted matte used as flux. From the advantages gained by the addition of roasted matte, it can be easily explained why only such a small amount of slag is added in working charges so rich in zinc.

At the Mutual Dillner Hütte, up to the year 1872, lead-slimes and larger amounts of slag from the same manipulation took the place of this matte, on account of there not being a sufficiency of the latter. Now, as the percentage of zinc has greatly increased of late in the lead-ores of Michaelstolleur, the above flux was not sufficient to effect an easy and effective smelting. It was necessary every three, or, at the highest, four weeks, to blow the furnaces out, on account of furnace-accretions and irregular working, and, moreover, the productions never amounted to more than 24 cwt. per twenty-four hours. The charge was now so made up, according to a previous one of the kind, that roasted lead-matte formed a portion, and the "Reichverbleiungs" slag was replaced by that from the matte-smelting, which contains a large percentage of iron, and the smelting carried on with a somewhat decreased pressure of blast. The results were much better, as compared with the former. In twenty-four hours over 54 cwt. of pure ore-charge was put through, exclusive of slag; the campaign lasts nearly eight weeks; less fuel was consumed, and the loss in metal was also much smaller.

The zinc, which principally goes into the matte and slag, becomes mechanically entangled in the slag, oversaturated as it is with bases, and is thus carried out of the furnace. The high percentage of zinc (about 12 per cent.) found in the slag is easily explained in this manner.

The average composition of the charges at the various works for a long time was as follows:

	1.	2.	3.	4.
	Schemnitzer.	Zsarnoviczer.	Neusohler.	Dillner.
	Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
Roasted lead-ore	46	45	47	60
Silver-ore	54	55	53	40
Raw matte	32	45	38	......
Lead-matte	3	......	......	15
Cupellation-products	38	42	47	20
Sweepings	8	4	2	12
Additional slag:				
Slag from same manipulation	50	50	50	......
Slag from matte-smelting	......	......	......	*54
Limestone	½	1	......	......

* Percentage.

In order to cover the auriferous silver, for every mint-pound of the same 2 to 2½ cwt. of lead is added. The products of this manipulation are:

a. Rich lead, containing 0.4 to 0.6 per cent. = 116 oz. 12 dwt. to 174 oz. 19 dwt. silver and gold; this goes to the cupellation-furnace, and has the following chemical composition at the Schemnitzer Hütte, No. 11:

Cu	0.148
Sb	0.095
As	trace.
Fe	0.019
Zn	trace.
AuAg	0.467
Pb	99.226
Residue	0.010

b. Lead-matte, containing from 0.075 to 0.15 per cent. = 21 oz. 17 dwt. to 43 oz. 15 dwt. silver and gold, 10 per cent. to 18 per cent. lead, and 6 per cent. to 15 per cent. copper.

According to chemical analysis, the lead-matte at the Schemnitzer Hütte is constituted as follows:

S	23.111
Fe	44.505
Pb	14.806
Cu	10.856
Sb	0.875
Au Ag	0.128
Mn	0.697
Ca O	0.450
Mg O	trace.
Residue	0.700

c. Furnace-dross sweepings and furnace-fumes go through the same process again.

The furnace-dross from the Dillner Hütte is constituted as follows:

Analysis No. 13.

S	27.689
Pb	20.269
Fe	14.000
Zn	32.237
Cu	0.664
Sb	0.058
Residue	6.000

d. Slag assaying from 0.003 to 0.006 per cent. = 17 dwt. to 1¾ oz. in silver and 1 per cent. to 3 per cent. lead.

Schemnitzer Hütte, analysis No. 14.

SiO_3	35. 372
Fe O	30. 710
Ca O	7. 716
Mg O	1. 716
Mn O	3. 783
Zn O	4. 633
Pb O	3. 041
Cu O	0. 261
Al_2O_3	10. 266
Ag	0. 002
S	1. 740

Dillner Hütte, analysis No. 15.

SiO_3	36. 333
Fe O	32. 650
Ca O	6. 345
Mg O	0. 785
Mn O } Zn O	12. 666
Pb O	2. 154
Cu O	0. 338
Al_2O_3	5. 000
Ag	0. 003
S	2. 754

In the smelting of 100 cwt. of the above charge the following was the production—

	At Neusohl.	At Schemnitz.	At Dillner.
	Per cent.	*Per cent.*	*Per cent.*
Bullion	27. 68	27. 94	26. 05
Lead-matte	8. 02	6. 70	9. 25
Furnace-dross, sweepings, &c	1. 55	5. 02	6. 00
Total	37. 25	39. 66	41. 30

Percentage of metal:

	Silver.	Gold.	Lead.
	Per cent.	*Per cent.*	*Percent.*
Bullion	96. 79	100. 57	93. 52
Matte	5. 69	1. 16	2. 57
Furnace-dross, sweepings, &c	0. 74	0. 60	1. 15
Total	103. 22	102. 33	97. 24

The smelting is conducted entirely in ordinary high blast-furnaces, 28 feet high, with two tuyeres, and in low blast-furnaces, 22 feet high, with two tuyeres.

The furnaces are tended by a smelter and a charger, who at the same

time wheels away the slag. The amount put through in twenty-four hours, without reckoning the slag, varies between 40 and 52 cwt. The consumption of fuel was different at the various works; it was as follows:

At the Schemnitzer Hütte, for every 100 cwt. of charge, 28 mass.

At the Dillner Hütte, for every 100 cwt. of charge, 80 mass.

At the Neusohler Hütte, for every 100 cwt. of charge, 105 mass.

438. *Matte-smelting.*—This operation treats the roasted matte from the "Reichverbleiung," silver-ores, roasted lead-copper-ores, cupellation-products, and lead for fluxing. The object of this operation, besides the concentration of the copper in the matte, is the extraction of the gold, silver, and lead from the lead-matte.

The products of this operation are:

a. Lead, carrying 0.25 to 0.4 per cent. = 72 oz. 18 dwt. to 116 oz. 12 dwt. auriferous silver.

b. Matte, containing from 0.07 to 0.4 per cent. = 20 oz. 9 dwt. to 116 oz. 12 dwt. auriferous silver, 15 per cent. to 28 per cent. copper, and 11 per cent. to 16 per cent. lead.

c. Furnace-dross, sweepings, &c.

d. Slag, (singulo-silicate) containing 0.002 to 0.004 per cent. = 11 dwt. 15.84 gr. to 1 oz. 3 dwt. 7.68 gr. auriferous silver, and 1 per cent. to 3 per cent. and 0.200 to 0.500 per cent. copper.

The smelting-charges were dissimilar at the different works. The following was the average "make-up" for three years:

	Neusohl.	Dillner.
Lead-matte	100 cwt.	100 cwt.
Silver-ores	20 cwt.	....
Lead-copper-ores	9 cwt.	10 cwt.
Cupellation-products	14	20
Flux-lead	52	....
Sweepings	8	20
"Reichverbleiungs" slag	56 per cent.	20 per cent.
Slag from ore-smelting	....	20 per cent.
Iron	1. 4 per cent.	....

From 50 to 70 cwt. of clean charge were put through in twenty-four hours.

The consumption of fuel was greatest at the Neusohler Hütte; about 140 mass to every 100 cwt. of charge. At the other works scarcely 100 mass were consumed. The reason of the larger consumption of fuel at the Neusohler Hütte, in all its smelting operations, is principally on account of the bad quality of coal.

439. *Second matte-smelting.*—The roasted matte from the foregoing operation is treated by this manipulatlon. The object of the operation is the same as that of the former. A charge generally consists of 100 cwt. of matte and 12 to 15 cwt. of cupellation-products. As flux, from 50 per cent. to 80 per cent. of slag from the ore-smelting is made use of. Lead is also added in order to effect a perfect extraction of the auriferous silver, as in the foregoing operation.

The products of the operation are:

a. Matte-lead, carrying 0.2 to 0.3 per cent. = 58 oz. 6 dwt. to 87 oz. 9 dwt. auriferous silver.

b. Copper-matte, carrying 0.04 to 0.08 per cent. = 11 oz. 14 dwt. to 23 oz. 7 dwt. auriferous silver, 40 to 50 per cent. copper, and 4 to 11 per cent. lead.*

According to chemical analysis, the copper-matte from Dillner Hütte, No. 16, contains the following percentage of constituents:

$Si\,O_3$	0.761
Fe	23.333
Pb	6.787
Cu	39.919
Sb	0.186
Zn	4.013
Au Ag	0.052
S	22.728
As	trace

c. Furnace-dross, sweepings, &c., &c.—The copper-matte from all the works is sent to the copper and silver extraction works in Tajova, for further treatment. As the gold in the copper-sweepings is not considered, when the same are dissolved at Tajova, it therefore remains to be noticed that the extraction of the gold from the auriferous-argentiferous charge is almost perfect by the Reichverbleiung operation and its finishing manipulations. While the amount of gold contained in a mint-pound of auriferous silver in the rich lead is equal to 0.020 to 0.030 per cent., 5 to 8 oz., so is the same in the matte-lead at the highest only from 0.005 to 0.007 per cent., equal to 1 to 2 oz., and in the copper-matte scarcely 0.0004 mint-pound, equal to 2 dwt., or the amount of gold contained in a cwt. of copper-matte containing 0.05 per cent., equal to 15 oz. auriferous silver, is scarcely 0.00002 mint-pound.

440. There was treated in the years 1868, 1869, and 1870, at the three governmental silver-smelting works, by the operation of "Reichverbleiung" and its finishing manipulations, the following amount of ores and metallurgical products:

Charge.	Material.	Dry weight.		Average amount of, contained in same.		
				Au Ag.	Lead.	Copper.
No.		*Cwt.*	*Lbs.*	*Mint lbs.*	*Lbs.*	*Lbs.*
1	Silver-ores and slimes	153.970	73	0.279	....	0.12
2	Lead-ores, slimes, and lead-copper ores	122.880	41	0.052	37.55	0.61
3	Metallurgical products	244.369	73	0.081	41.72	2.20
	Total	521.119	187	0.412	79.27	2.93

* The analyses 1, 2, 3, 4, 5, 7, 9, 11, 12, and 14 were made by the royal Hungarian district analyst, Carl Dobrovitz, and Nos. 6, 8, 10, 13, 15, and 16 by the author, Josef Wagner.

The following was the production of metal in percentage:

	Gold and silver.	Lead.	Copper.
	Per cent.	*Per cent.*	*Per cent.*
Production	104. 86	97. 58	107. 49
Surplus	4. 86	....	7. 49
Loss	....	2. 42	....

Consumption of fuel for total amount treated:

	Per cent. of charge.
Wood, (3 feet long,) 6,813 klafter	0.013 klafter.
Charcoal, 548,451 mass	1.052 mass.

EXPENSES.

	On total amount treated. Florins.	Kr.	On per 1 cwt. of charge. Kreutzer.
a. Cost of fuel	248,209	54	47.62
b. Cost of manipulation and general expenses	172,342	19	33.06
c. Superintendence	39,358	57	7.55
Total	459,910	30	88.23

If calculated per 1 cwt. of ore and slime, it would be=1 florin 66.17 kreutzer.

At the Mutual St. Michaelstollner-Dillner Hütte there is smelted annually over 20,000 cwt. of ore, &c. The total cost per cwt. of ore and slime in 1872 was equal to 1 florin 45 kreutzer.

441. *III.—Cupellation.*—The auriferous-argentiferous lead coming from the "Reichverbleiung" operation and its finishing manipulations is cupelled; also silver-ores assaying higher than 3 per cent.=874 oz. are manipulated by this process. This operation is conducted in a German cupellation-furnace with movable top, and which is furnished with a Siberian litharge-reduction furnace. From 200 to 250 cwt. lead are cupelled at a time. The operation is so conducted that about half the litharge produced is immediately reduced to lead by means of the reduction-furnace. The products of this operation are:

a. Auriferous blick-silver, having a fineness of 980 to 992 in 1,000 parts.
b. Manipulation litharge
c. "Abstrich"
d. Test
} are resmelted.
e. Lead from the reduction of litharge is liquated for commercial lead.
f. Red and green commercial litharge.

442. In the years 1868, 1869, and 1870 there was cupelled by the government silver-smelting works about 143,688 cwt. of lead, containing very nearly 0.500 mint-pound gold per cwt. of auriferous silver.

The metallic production of auriferous silver in per cent. was:

	Per cent.
As blic-silver	96.25
In the products	4.24
Total	100.49
Consequently there was a surplus of	0.49

Average loss in lead amounted to about 5 per cent.

TOTAL EXPENSES.

	Florins.	Kr.	Per mint-pound of silver produced. Fl.	Kreutzers.
a. Cost of fuel	20,712	98		31.5
b. Cost of manipulation and general expenses	42,737	65		65.5
c. Superintendence	8,886	50		13.5
Total	72,337	13	1	10.5

443. *IV. Liquation.*—As a part of the very impure lead is liquated before undergoing the operation of cupellation, consequently this operation can only be considered as a preliminary manipulation to the cupellation, and the refining of the litharge-lead to commercial lead can only be considered as the actual liquation operation. The operation of liquation, including the refining, is conducted in a combined lead liquation and refining furnace, which was first brought into use in the year 1860, at the Schemnitzer works, by Superintendent Willibald Kachelmann. The same consists of two principal parts, *i. e.*, a reverberatory and a kettle furnace, each with its own fire-place. The kettle furnace, which has a cast-iron kettle capable of holding 50 cwt. of lead, stands close up to and under the reverberatory furnace, which is furnished with a spout, through which the liquated lead flows into the kettle. The liquated lead is refined by means of green birch-tree branches, which are immersed into the lead-bath, and held there by means of a special arrangement.

The general costs of liquation in per cent. of lead amounted to:

	Florin.	Kr.
a. Cost of fuel	1	90
b. Cost of manipulation and general expenses	6	79
c. Superintendence	1	30
Total	9	99

444. Total cost of the lead and silver smelted during the years 1868, 1869, and 1870:

	Florin.	Kr.
I. Cost of the ore-smelting	153, 626	96
II. Cost of the Reichverbleiung and finishing manipulations	459, 910	30

	Florin.	Kr.
III. Cost of the cupellation	72,337	13
IV. Cost of the liquation	2,924	99
Total	688,799	38

The loss in lead amounted to 8,438 cwt. 47 lbs., or 5.5 per cent. of the production; the same represents a value, according to the tariff, of 107,158 florin, 77.9 kreutzer.

Cost of production:

a. For silver-ores and slimes.

1. There was smelted:

Operation.	Ores and slimes.		Auriferious silver.		
			Assay.	Amount.	
			Mint-pounds.		
	Cwt.	*Lbs.*			
Ore-smelting	162,784	94	0.071	12,068	850
"Reichverbleiung" operation	153,970	73	0.271	41,831	833

Cost thereof:

	Florin.	Kr.
Ore-smelting	153,626	96
Reichverbleiung, and finishing manipulation, per cwt. 166.17 kreutzer	255,699	41
Cupellation according to the contents in silver	66,671	63
Loss in lead by cupellation	95,803	28
Total	571,801	28

The complete manipulation of a cwt. of silver-ore or slime, containing 0.170 mint-pound = 49 oz. 10 dwt. 4.80 gr. auriferous silver, costs 1 florin 97 kreutzer.

b. For lead and lead-copper ores and slimes.*

1. There was smelted:

Ores and slimes.	Average contents.		Contents.			
	Au and Ag	Pb	Gold.	Silver.	Lead.	
			Mint-pounds.	*Mint-pounds.*	*Cwt.*	*Pounds.*
122,880 cwt. 41 pounds	0.052	37	6,389	855	46,142	61

Cost of smelting the above:

	Florin.	Kr.
Cost of smelting per cwt. 166.17 kreutzer	204,210	80
Cost of cupellation according to the amount of silver	7,665	50

* The loss in lead resulting from smelting and liquation, and which was subtracted from the metallic contents in the redemption of the dross, is not considered in the above statement of expenses.

	Florins.	Kr.
Loss of lead in cupellation according to the amount of silver	11,355	50
Cost of liquation	2,924	99
Total	226,156	79

The complete manipulation of a cwt. of the charge, containing on an average 0.052 mint-pounds = 15 oz. 3 dwt. 6.24 gr. auriferous silver, and 37 per cent. lead, costs 1 florin 84 kreutzer.

c. For auriferous silver produced.

There was produced 63,152.986 mint-pounds auriferous silver, containing 0.0192 mint-pound gold = 5 oz. 11 dwt. 20.31 gr.

Cost of production:

	Florin.	Kr.
Total cost ore-smelting	153,626	96
Total cost of Reichverbleiung of the silver-ores	255,699	41
Total cost of cupellation	72,337	13
Loss in lead by cupellation	107,158	77
Total	588,822	27

The production of a mint-pound of auriferous silver (0.0192 mint-pound gold and 0.9808 mint-pound silver) having a value of 57 florin 52 kreutzer, costs 9 florin 32 kreutzer.

d. For liquated lead and commercial litharge.

Only such lead as was actually refined at the silver-smelting works, as liquated lead, and such litharge as was produced during the operation of cupellation, is here taken into account. The production is regulated according to the demand; if, for example, the demand for the same increases, more is consequently produced.

1. About 33,493 cwt. of liquated lead and commercial litharge was produced. The costs thereof were:

	Florin.	Kr.
For smelting the lead-ore	204,210	89
For liquation	2,924	99
	207,135	88

The production of a cwt. of liquated lead or litharge, costs 6 florins 18 kreutzer, and is worth 14 florins.

Besides the production of blick-silver, lead, and litharge, there was also produced at the three government silver-smelting works, in addition to the above, 4,641 cwt. 77 lbs. of copper-matte, carrying on an average 44 per cent. copper, and 0.094 mint-pound = 27 oz. 8 dwt. 2.88 gr. silver, which represents a value, according to the tariff, of 119,693 florins 36 kreutzer.

They have also to share a part of the above costs of production. If these are brought into the account, the cost of producing a mint-

pound of auriferous silver and a hundred-weight of liquated lead and litharge is somewhat less.*

445. B. COPPER-SMELTING.—The following ores and products are utilized by this manipulation:

a. Argentiferous copper-ore containing, on an average, 12 per cent. copper and 0.040 mint-pound silver = 12 oz.

b. Non-argentiferous copper-ore (*gelferz*) containing 18 per cent. copper and upward.

c. Precipitated copper from the mine-waters.

d. Mint-cement, copper, and copper-sweepings.

e. Copper-matte, from the silver-smelting works, containing 40 per cent. copper and upward, 4.11 per cent. lead and 0.080 mint-pound = 23 oz. 6 dwt. 12.40 gr. silver.

The argentiferous, as well as the non-argentiferous, ores and products are worked separately. There are two smelting-works running. The Altgebirg has the preliminary work and production of copper.

446. The following are the different manipulations:

I. Smelting for argentiferous matte.
II. Smelting of the roasted argentiferous matte, (*Röstdurchstechen.*)
III. Smelting of the roasted lead-products.
IV. Extraction of silver from black copper.
V. Reduction of the dross and sweepings.
VI. Smelting of the furnace-dross, resulting from the smelting of the non-argentiferous copper-ores, (*gelbfabzugschmelzen.*)
VII. Refining.

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* In the year 1858, at the Schemnitzer Hütte, the combined methods of silver-extraction, according to Ziervogel, and gold-extraction, according to Plattner, were adopted for the extraction of silver and gold from the matte.

The manipulations in this process are as follows:

a. Smelting of the poor argentiferous pyritous ores for matte.

b. Crushing the matte.

c. Roasting the finely crushed matte. The object of this operation was to transform the argent sulphide contained in the matte into argent sulphate.

d. Dissolving the silver out of the roasted powder with hot water and the precipitation of the same with copper.

e. Precipitation of the copper in solution from which the silver has been extracted by means of old iron.

f. Chlorination of the residue from the silver-extraction in order to transform the gold into gold chloride.

g. Dissolving the gold chloride formed in hot water and precipitation of same by means of an iron-vitriol solution.

The residues from this extraction process are used as a basic-flux in the smelting operations.

It cost, in 1862, 36 florins to extract a mint-pound of auriferous silver according to this process.

Although the ores treated by this process have never contained more than 0.09 per cent. = 26 oz. 5 dwt. auriferous silver, still the results could not be compared with those obtained with the "Reichverbleiung" operation; consequently, in the year 1864, the above process of extraction was done away with.

447. *I. Smelting for argentiferous matte.*—Argentiferous copper-ores and unroasted furnace-dross from the same operation are utilized by this manipulation. The following is the average "make-up" of a smelting-charge for the years 1868, 1869, and 1870:

	Per cent.	
Argentiferous copper-ore	97.33	= 100 per cent.
Unroasted furnace-dross	2.67	
Limestone	80.00	
Slag resulting from the smelting of roasted matte	59.00	

The smelting was conducted in two blast-furnaces, 28 feet high, with two tuyeres. This manipulation has for its object the concentration of all the copper and silver into a matte. The products of this manipulation and their amount in percentage from the above charge were as follows:

1. Raw matte, 24.69 per cent., carrying 34.68 per cent. copper and 0.156 mint-pound = 45 oz. 6 dwt. 13.92 gr. silver.

2. Antimonial speiss, amounting to 0.89 per cent., and containing 25.08 per cent. copper and 0.204 mint-pound = 59 oz. 9 dwt. 7.68 gr. silver.

3. Raw furnace-dross, 2.70 per cent., containing 4 per cent. copper and 0.010 mint-pound = 2 oz. 18 dwt. 4.80 gr. silver.

There was no loss in metal of any kind. The quantity put through each furnace in twenty-four hours was 78 cwt. of ore and dross. The consumption of fuel per 100 cwt. amounted to 166 mass, or 1,075 cubic feet.

The raw matte is roasted twelve times in free heaps. The consumption of wood was equal to 7.72 cubic feet per hundred-weight of matte.

448. *II. Smelting of the roasted argentiferous matte*, (*Röstdurchstechen.*)—Besides the roasted matte, roasted copper-oberlech, (matte,) dross, unroasted speiss, (on account of the easier breaking up of the black copper,) and siliceous argentiferous copper-ores are treated in this manipulation.

The average smelting-charge, in per cent., for three years, was as follows:

	Cwt.
Roasted matte	68.80
Oberlech matte	12.44
Furnace-dross	3.70
Speiss	2.30
Ore	12.76
Total	100.00

The smelting was conducted in low blast-furnaces, having two tuyeres; 50 to 80 per cent. slag from the matte-smelting was added to the above charge. The products from this manipulation in treating the above charge were as follows:

	Per cent. of the production.
1. Black copper	38.84
2. Oberlech	12.30
3. Dross	3.70

The oberlech and dross, after having been roasted, pass through the same operation again, while the black copper, containing 80 to 85 per cent. copper and 0.250 to 0.256 mint-pound = 74 oz. 13 dwt. 13.92 gr. silver, is sent to the silver-extraction.

There was put through in twenty-four hours 76 cwt. of charge, and the consumption of fuel per 100 cwt. of same amounted to 80.11 *mass*, or 517.71 cubic feet.

449. *III. Smelting of the roasted lead-products*, (*Rostdurchstechenbleischer Geschicke.*)—The copper-matte from the silver-smelting works, and also the silicious-argentiferous copper-ores, are treated in this operation. This operation is incidental with the former roasting-operation. The following are the products of the operation:

1. Black copper, sent to the black-copper extraction-furnace.
2. Oberlech } pass through the same operation.
3. Dross }

450. *IV. Extraction of black copper.*—By this operation black copper, free from lead, and that also which contains lead, are treated together, in a certain proportion to each other; also, cement-copper, oxide of copper, liquated copper, rich dross, &c. The following are the various operations:

1. Preliminary operations, consisting in—

a. Breaking of the black copper into pieces, which is partly accomplished in the operation of smelting for matte.

b. Crushing and stamping the black copper and assortment of the black-copper crushings.

c. Chloridizing-roasting of the black copper-crushings by means of salt; a difference is also made in this operation between the preliminary roasting and good roasting, as the length of the operation depends upon the amount of salt used, and this again upon the percentage of copper and silver contained in the charge. The operation generally lasts ten hours when 10 per cent. of salt is used for chloridizing a charge containing 0.250 mint-pound = 72 oz. 17 dwt. 14.40 gr. silver. The success of the extraction greatly depends upon the perfection of the roasting.

d. Screening and sorting of the roasted black-copper crushings. The lumps of incompletely roasted matte, after having been separated from the well roasted, are ground to powder and then roasted over again.

2. Extraction of the well roasted black-copper crushings.

a. Lixiviation of the roasted powder with cold solution of salt; the products are: Rich solution, out of which the silver is precipitated; poor solution, from which the copper is precipitated.

b. Washing of the extracted powder with hot water; the wash-water is carried to the solution out of which the copper is to be precipitated. It takes on an average fifteen hours to lixiviate a charge of 400 to 500 pounds. The wasted residue is tested for silver; if it contains 0.009 mint-pound = 2 oz. 12 dwt. 11.52 gr. silver, or less, the same is given over to the copper-manipulation; if it contains over 0.009 mint-pound = 2 oz. 12 dwt. 11.52 gr. silver, it is dumped on a warm place, where the process of chlorination continues of itself, and after some time it is again lixiviated.

c. Precipitation of the silver from the rich solution by means of copper granules. The cement-silver produced in this manner is washed out with hot water, pressed, dried, and melted in a graphite crucible, with a slight addition of borax and potash. The melted silver is poured into molds, and sent to the mint in Kremnitz.

d. Precipitation of the copper from the desilverized rich solution, poor solution, and wash-water with iron. The cement-copper, produced in this manner, and which always contains some silver, again passes through the process of extraction.

In 1868, 1869, and 1870 there was treated, inclusive of the intermediate products obtained by the process, 9,267 cwt. 51 lbs. ore, carrying 7,103 cwt. 60 pounds copper and 2,908.718 mint-pounds silver. The production was: metallic silver, 2,620.829 mint-pounds; by-products and residues, 221.092 mint-pounds; with 7,102 cwt. 76 lbs. copper. Total 7,102 cwt. 76 lbs. copper and 2,841,921 mint-pounds silver.

Loss in copper was equal to 0.01 per cent., in silver 2.27 per cent. = 661 oz. 14 dwt. 4.80 gr.

451. *V. Reduction of residues.*—This operation treats the extraction-residues, copper-dross, unroasted "*gelf oberlech,*" (copper-matte,) refining-dross, cement-powder and products from the "*Neusohler Kupferhammer.*" The object of this operation is the reduction of the residues from the extraction-operation and the desulphurization of the matte. This is effected at a red heat, by means of the mutual reaction of the oxides upon the sulphides, whereby sulphurous acid is formed and disengaged. This manipulation is conducted in a "*spleissofen,*" (refining-furnace.) The following are the products of this operation:

1. Reduction-copper, which is refined.
2. Reduction-dross,
3. Reduction-matte, } go to the dross-smelting.
4. Reduction "abstrich,"

452. *VI. "Gelfabzugschmelzen," smelting of non-argentiferous dross.*—The reduction dross, matte, and abstrich, refining-dross, refining-abstrich, and hearth, copper-scales, furnace-dross, and non-argentiferous ores are treated in this manipulation. This operation is similar to the other, the only difference is, that it is conducted in low blast-furnaces. The following are its products:

1. Gelf-dross copper, which is refined.

2. Gelf-dross matte, goes to the residue-reduction.
3. Gelf dross furnace dross, to pass through the same operation again.

453. *VII. Refining.*—Non-argentiferous copper, reduction-copper, "matraer" copper, and copper-scales are treated in this operation. The operation is conducted in an ordinary refining-furnace, using wood as fuel. The products of this operation are:

1. Refined copper, which is taken to the copper-mill in Neusohl.
2. Granulated copper, used for precipitating the silver in the rich solution.
3. Refining-dross,
4. Refining-hearth, } taken to the dross-smelting.
5. Crucible-dross,

454. Total costs of the copper-smelting during the years 1868, 1869, and 1870:

Altgebirg.

	Fl.	Kr.
I. For smelting for argentiferous matte } II. For resmelting of roasted argentiferous matte }	66,082	54½

Tajova.

	Fl.	Kr.
III. Smelting of roasted lead-ore	5,581	87½
IV. Extraction of black copper	29,202	76
V. Reduction of residues	11,803	85
VI. Smelting of non-argentiferous dross	8,416	82
VII. Refining	11,658	35½
Total	132,746	20½

The costs of I, II, III, V, VI, and VII belong to the copper-production, IV to the silver-production. Production of refined copper, 8,600 cwt. 77¾ lbs.; production of silver, 2,620,892 mint-pounds.

The expense, therefore, for the production of a hundred-weight of refined copper, worth 60 florins, 12 florins 03 kreutzer. The production of a mint-pound of silver, worth 45 florins, 11 florins 14 kreutzer.

455. C. RE-IMBURSEMENT OF ORES AND SLIMES FROM THE MINES BY THE LOWER HUNGARIAN GOVERNMENT SMELTING-WORKS.—At the present time there are two regulation-tariffs for the purchase of ores, slimes, &c.

I. For gold, silver, lead, and lead-copper ores.

II. For argentiferous and non-argentiferous copper-ores.

In planning the tariff, the actual costs of metallurgical treatment from the previous year were taken for its basis, at the same time taking into consideration the increased price of fuel and wages, which has taken place since that time.

For the planning of the present regulation-tariff, that is, for the present year, 1873, the results of manipulation for the years 1868, 1869, and 1870 were taken as a basis upon which to construct.

The Vienna centner (hundred-weight)=112 zoll-pounds, serves as the weight unit in the purchase of all ores.

Purchasable ore; all ores in which the metallic value, capable of extraction, is not completely covered by the "metal-calo" and the gold reduction given below.

The purchase-price of the gold is fixed at 697 florins 50 kreutzer, "O. W.," in gold per mint-pound; for silver, 45 florins. The price paid for the copper and lead depends upon the market price. At present 12 florins 75 kreutzer is paid for lead, (paper money,) and for copper 49 florins per cwt.

The assay-sample for ores and slimes is generally taken from 100 cwt. Their metallic contents are then determined, the various assay-results averaged; then the worth of the ore, &c., is calculated from the average assay-result, and paid for according to existing and known regulations.

456. *a. Assay equalization-tariff.*

Matte assay.		Lead-assay.		Copper-assay.		Gold-silver assay.		Gold-assay.		
Matte contents.	Equalization difference.	Lead-contents.	Equalization difference.	Copper-contents.	Equalization difference.	Containing auriferous silver up to—	Equalization difference.	Containing gold in mint-pounds up to—	Equalization difference with gold contents— To 0.050	Over 0.050
	Vienna pounds.	*Vienna pounds.*	*Vienna pounds.*	*Vienna pounds.*	*Vienna pounds.*	*Mint-pounds.*	*Mint-pounds.*	*Mint-pounds.*	*Mint-pounds.*	*Mint-pounds.*
No difference	5	To 30	2	From 2.......	½	0.005	0.001	0.005	0.002	0.001
				From 4.......	¾	0.010	0.002	0.010	0.004	0.002
		Over 30	....	From 10.......	1	0.030	0.003	0.020	0.008	0.004
		To 40	4	From 20.......	2	0.050	0.005	0.030	0.010	0.006
				From 40.......	4	0.100	0.010	0.050	0.015	0.008
				From 70.......	4	0.200	0.015	0.100	0.020	0.010
		Over 40	6	And over	6	0.400	0.023	0.500	0.030	0.015
						0.600	0.030	1.000	0.030	0.020
						0.800	0.040	....	....	....
						1.000	0.050	....	....	....
						1.500	....	....	....	....
						Over........	0.060	....	....	....

Assay tariff.

	Assay.			
	Examination.		Purchase.	
	Fls.	*Kr.*	*Fls.*	*Kr.*
1. Gold-assay:				
a. Argentiferous dross containing from 0. 000 to 0. 030 mint-pounds Au. Ag..	14	07	28	14
Argentiferous dross containing from 0. 030 to 0. 060 mint-pounds Au. Ag...	9	12	18	24
Argentiferous dross containing from 0. 060 to 0. 100 mint-pounds Au. Ag...	6	60	13	20
Argentiferous dross containing from 0. 100 to 0. 200 mint-pounds Au. Ag...	4	63	9	26
Argentiferous dross containing from 0. 200 to highest mint-pounds Au. Ag..	3	26	6	52
b. Lead-dross containing from 0. 000 to 0. 030 mint-pounds Au. Ag.........	12	40	24	80
Lead-dross containing from 0. 030 to 0. 060 mint-pounds Au. Ag............	8	31	16	62
Lead-dross containing from 0. 060 to 0. 100 mint-pounds Au. Ag............	6	74	13	48
Lead-dross containing from 0. 100 to 0. 200 mint-pounds Au. Ag............	4	56	9	12
Lead-dross containing from 0. 200 to highest mint-pounds Au. Ag	3	41	6	82
2. Silver-assay of ores, slimes, mattes, &c..............................	......	31	......	93
3. Lead-assay of ores, slimes, mattes, &c................................	......	43	1	29
4. Copper-assay of ores, slimes, mattes, &c..............................	......	66	1	98
5. Silver-assay of lead-metal	......	7	......	21
6. Matte-assay of ores, slimes, mattes, &c...............................	......	23	......	69
7. Silver-assay of *blick-silver*..	......	14	......	42

457. *Metallic deduction.*—1. *Gold and silver.*—There is no allowance made for loss in gold and silver in the assay of ores and slimes. In the assay of auriferous-argentiferous copper-dross, poor in lead, and dross containing copper, gold, and silver, also mint-sweepings and sweepings from other establishments, and, lastly, rich lead, 2 per cent. is subtracted from the amount of gold and silver found in assay.

458. 2. *Lead-contents.*—In determining the lead-deduction for the different lead-ores, the quantity of slag which they would produce was taken into consideration; for pyritous lead-slimes a small "lead-calo" is put in, as well as for silicious lead-ores having the same metallic contents.

In the year 1873 there was put in the purchase-tariff for lead-percentage in the lead-dross, the following deductions, irrespective of the auriferous silver-contents:

	Lead contents in a Vienna centner.					
	10–19	20–29	30–39	40–49	50–59	60–highest.
	Lead deduction in percentage.					
Of lead-ores and lead-copper ores	22	19	16	13	10	7
Of lead-slimes and lead-copper slimes................	15	13	11	9	7	6

459. SMELTING EXPENSES.—In determining the smelting-cost of ores, slimes, sweepings, &c., containing different amounts of the metals, the amount of slag producible from them was also taken into consideration, and in the year 1873 the following smelting-costs were put in:

(a) Of silver-ores, &c.

Gold and silver contents.		Having a matte contents per hundred-weight in pounds.							
		0–19	20–29	30–39	40–49	50–59	60–64	65–69	70–∞
		Cost in kreutzer of a Vienna centner for smelting.							
Containing no zinc or antimony.	From 0.001 to 0.100.	251	217	183	149	85	48	21	*+32
	From 0.100 to 0.200.	254	224	194	164	104	69	44	*+ 8
	From 0.200 to 0.300.	261	234	207	180	123	90	66	†18
	From 0.300 to ∞ ..	267	243	219	195	141	109	87	†43
Containing antimony	From 0.001 to 0.100.	278	244	210	176	112	75	48	*+ 6
	From 0.100 to 0.200.	278	248	218	188	128	93	68	†18
	From 0.200 to 0.300.	278	251	224	197	140	107	83	†36
	From 0.300 to ∞ ..	279	255	231	207	153	121	99	†55
Containing zinc...............	From 0.001 to 0.100.	291	257	223	189	125	88	61	*+ 7
	From 0.100 to 0.200.	291	261	231	201	141	106	81	†13
	From 0.200 to 0.300.	291	264	237	210	153	120	96	†49
	From 0.300 to ∞ ..	292	268	244	220	166	136	112	†68

* Premium. † Figures.

(b) Of lead-ores, &c.

Contents in gold and silver.		Lead contents per hundred-weight.						Bullion and rich lead.
		10–19	20–29	30–39	40–49	50–59	60–∞	
		Numbers for each hundred-weight kreutzer.						
Silicious lead-ores and lead-copper ores.	Containing no Au. Ag.	493	424	355	286	217	148	10
	From 0.001 to 0.100...	507	438	369	290	131	162	24
	From 0.100 to 0.200...	535	466	397	328	259	190	52
	From 0.200 to 0.300...	564	495	426	357	288	219	81
	From 0.300 to ∞.....	592	523	454	385	316	247	109
Pyritous lead-slimes and lead-copper slimes.	Containing no Au. Ag.	227	200	173	146	119	92	......
	From 0.001 to 0.100...	241	214	187	160	133	106	......
	From 0.100 to 0.200...	269	242	215	188	161	134	......
	From 0.200 to 0.300...	298	271	244	217	190	163	......
	From 0.300 to 0.∞ ...	326	299	272	245	218	191	......

Auriferous-argentiferous copper-dross, poor in lead, is considered equal to silver-dross when it contains at least 5 to 9 per cent. lead and 1 per cent. copper. Copper-dross, however, when containing 10 per cent. and over of lead per cwt., costs the same as lead-dross for smelting. Besides this, the auriferous-argentiferous copper-dross carrying lead and auriferous-argentiferous dross containing copper must pay for extraction 4 kreutzer per pound of refined copper, and for production of copper $2\frac{1}{2}$ kreutzer per pound of refined copper.

460. *e. Cost of superintendence of smelting-operations.*—For the costs of superintendence 5 per cent. is deducted from the cost of smelting.

461. *f. Cost of administration.*—Two per cent. is also deducted for these costs. The deductions in *a*, *e*, and *f* are payable in paper money.

462. *g. Interest on the purchasing-capital.*—From the calculated free-gold contents of the products which contain over 0.200 mint-pound, 2 per cent. is deducted; when they contain less than this amount, 3 per cent. is deducted. From the gold, the percentage deducted is in gold;

and from silver, in silver money; but for copper and lead, the deduction is payable in paper money.

463. *h. Duty for gold-extraction.*—For every mint-pound of auriferous silver there is a tax of 1 florin, gold.

464. *i. Mint-charges.*—One-half per cent. of the value of the gold and 1 per cent. of the value of silver is deducted for coining.

465. *Example.*—Purchased 100 cwt. (dry weight) of auriferous slimes, carrying on an average 0.300 mint-pound = 87 oz. 8 dwt. 14 gr. auriferous silver, the same containing 0.013 gold per mint-pound (= 3 oz. 15 dwt. 16.32 gr. gold per ton of 2,000 pounds) of silver and with 50 per cent. matte.

Metallic contents in mint-pounds.

	Fl.	*Kr.*	*Fl.*	*Kr.*	*Fl.*	*Kr.*
Silver, 29.610 per mint-pound, 45 florins value	1,332	45				
Gold, 0.390 per mint-pound, 697.50 florins value	272	02.5				
			..	..	1,604	47.5
DEDUCTIONS.						
Assay-tax:						
Gold-assay	6	52				
Silver-assay	..	62				
Matte-assay	..	69				
			7	83		
Smelting-costs per hundred-weight with a matte contents of 50 pounds, 1 florin 41 kreutzer per 100 hundred-weight	..	..	141	..		
Cost of administration, 5 per cent of the smelting-costs	..	..	7	05		
Chief superintendship costs, 2 per cent	..	..	2	82		
Gold-extraction tax, 1 florin per mint-pound auriferous silver	..	..	30	..		
Mint-tax of value of gold, ½ per cent	1	36				
Mint-tax of value of silver, 1 per cent	13	32				
			14	68		
Total deduction					203	38
Remaining metallic value					1,401	09.5
Therefrom 2 per cent					28	02
Remaining balance in money					1,373	07.5

The total free value of a Vienna centner containing the above amount of auriferous silver is, therefore, 13 florins 73 kreutzer, or, per zoll-centner, 12 florins 26 kreutzer.

466. II. PURCHASE-REGULATIONS FOR ARGENTIFEROUS AND NON-ARGENTIFEROUS COPPER-ORES AND OTHER COPPER PRODUCTS.

Redemption, assay, averaging of assay results, and payment are performed according to the known regulations.

Purchasable, every amount of copper product from which the producible metallic contents is not covered by the money deduction as given below.

a. An assay-tax is deducted from every load purchased.

	Examination. Kreutzer.	Purchase. Fl. Kr.
1. Copper-assay	52	1 56
2. Silver-assay	33	99

b. The equalization of the assay is done in the same manner as in the silver-lead tariff.

c. Metallic deduction.

1. Copper-deduction.

The result obtained by fire-assay of the ores, slimes, and metallurgical products remains unchanged; that is, there is no deduction made for the loss in copper in the assay, but from the industrial and mint products and sweepings, 1 per cent. copper is put in.

2. Silver-deduction.

The deduction for the manipulation of silver is, when containing less than 24 pounds copper, 9 per cent.; when containing from 24 to 69 pounds copper, 7 per cent.; when containing from 70 to ∞ pounds copper, 3 per cent.

Sweepings, mint, and industrial products, must deduct for "silver-calo." When containing less than 24 pounds copper, 10 per cent.; when containing from 24 to 69 pounds copper, 8 per cent.; when containing from 70 to ∞ pounds copper, 4 per cent.

d. There is demanded for costs of smelting products:

1. Cost of copper production from every hundred-weight ore, &c., containing less than 24 pounds of copper, 2 florins 36 kreutzer; containing from 24 to 69 pounds, 2 florins 22 kreutzer; containing from 70 to ∞ pounds, 1 florin 36 kreutzer.

2. Cost of desilverization for every pound of copper is 4 kreutzer.

3. For administration of smelting-works there is a deduction of 17 per cent. of the smelting costs.

4. Chief-superintendentship, a deduction of 4 per cent., as above.

e. For coining there must be paid in silver coin 1 per cent. of the amount of silver produced.

f. Interest for delay on the purchasing-capital = 3 per cent.

The net profit of the silver and copper smelting-works is divided among the sellers according to the amounts sold by each and also according to the determined metallic value of the smelted products. This division is made annually after the calculations have been proved to be correct, by appointed commissioners. If there should be a loss, however, the same is charged to the sellers in the next year in proportion to the smelting-costs.

D. GENERAL CONSIDERATIONS UPON THE LOWER HUNGARIAN METALLURGICAL PROCESSES AND FURTHER COMPARISON OF THE TARIFFS FOR THE PURCHASE OF ORES AND METALLURGICAL PRODUCTS AT THE GOVERNMENTAL SMELTING-WORKS IN THE UPPER HARZ AND FREIBERG, WITH THE PURCHASE-TARIFF IN VOGUE AT SCHEMNITZ.

467. If one follows the Lower Hungarian smelting processes since the year 1852 up to 1873, it will be perceived that from year to year improvements have been made, especially in the smelting manipulations. In 1862, for example, the production in twenty-four hours by the "Reichverbleiung" process was scarcely 26 cwt., while at the present time the

same reaches 50 Vienna cwt. = 56 Zoll-cwt. at the Schemnitzer and Dillner Hütte, and with diminished consumption of fuel, as compared with former years. Also with the cupellation operation there is no fault to be found, the lead-loss being only 5 per cent., whereas at other works the same lies between 7 and 10 per cent.

The mining-accounts give us proof of the advancement made in the Lower Hungarian metallurgical processes, for examples:

In the year 1852, the Johann-Nepomuker Gewerkschaft sold 206 mint-pounds of auriferous silver, having the calculated value, according to the ore-tariff, of 65,165 florins 31 kreutzer, or, per mint-pound, of 35 florins 18 kreutzer. In the year 1872, the same mining company sold ore of the same assay-value, and containing 633,231 mint-pounds auriferous silver, and received for the same, according to the ore-tariff, the sum of 27,671 florins 89 kreutzer, or, per mint-pound, 43 florins 69 kreutzer. If now the lawful tax of the year 1852, of 3 florins 50 kreutzer per mint-pound auriferous silver, be deducted, we have a difference (43.69 — 350) — (35.18) = 5 florins per mint-pound auriferous silver in favor of the ore-tariff of the year 1872, which can only be explained by the diminished smelting and administration costs. This can also be shown in the trades made by the other mining-companies.

On the other hand, from year to year, the price of wages and fuel have been continually on the increase; in 1852 a roaster received, per shift, 42 kreutzer, a smelter 50 kreutzer. In 1872 a roaster received, per shift, 70 kreutzer, a smelter 80 kreutzer. Fuel, per "mass,"=6.4 cubic feet, cost, in 1852, 35 kreutzer. Fuel per mass, 1872, cost 80 kreutzer. When all this is taken into consideration, one will clearly perceive that the metallurgical operations have made great progress in improvements.

468. In order to have a clear idea of how the Lower Hungarian smelting costs compare with those of other metallurgical establishments, the author will take the smelting-works of the Upper Harz and Freiberg as examples, which stand, as is well known, in the first rank in Germany, by their perfect preliminary treatment of their products, accompanied with the profitable production of all the—to the smelting operations—disadvantageous ingredients, such as sulphur, arsenic, zinc, &c., and by their treatment of immense quantities.

In the "*Berliner Zeitschrift für das Berg-Hütten und Salinenwesen*," which published in 1872 the new ore-tariffs of the Upper Harz, Freiberg, and the Mansfeldischen Gewerkschaft in Eiselben, it reads in Circular 2 of June 1, 1871: "It is the intention of the undersigned smelting-administrations to give the greatest possible enco uragement to the import ation of foreign ores to German harbors, for the interests of German industry; and for the purpose of effecting this object, the prices stated in the following tariff for ores have been placed at such a high figure that only the interest upon the working capital and the costs of manipulation are covered with any certainty," &c.

As the Schemnitzer ore-tariff for 1873 was constructed on the same principle, the author, in order to solve the above question, makes a comparison here of both tariffs.

I.—*Table for silver-ores.*

[Kremnitz auriferous slimes.]

Contents per Vienna centner.			Contents per Zoll-centner.		Payment according to the ore-tariff of—						Greater or smaller price in comparison with the Upper Harz and Freiberg tariff.		
Auriferous silver.	Amount of gold in a mint-pound of silver. (Mint-pound = 500 grams.)	Matte contents.	Auriferous silver.	Amount of gold in a mint-pound of silver. (Mint-pound = 500 grams.)	Schemnitz, Lower Hungary.				The fiscal smelting-works of Upper Harz, Freiberg, &c.				
					V. centner.		Z. centner.		Z. centner.				
Mint lbs.	*Mint lbs.*		*Mint lbs.*	*Mint lbs.*	*Fl.*	*Kr.*	*Fl.*	*Kr.*	*Fl.*	*Kr.*		*Fl.*	*Kr.*
					+	32		28.5					
0.010	0.200	70	0.007	0.0017	1	39	1	24.5	1	12	+	—	41
					+	32		28.5					
0.030	0.100	70	0.024	0.0026	2	87	2	56	1	88	+	—	96.5
					+	32		+28.5					
0.070	0.060	70	0.054	0.0037	6	43	5	64	3	66	+	2	26.5
0.100	0.013	0	0.058	0.0011	2	30	2	06	3	45	—	1	39
0.100	0.013	30	0.088	0.0011	2	92	2	61	3	45	—	—	84
0.100	0.013	50	0.088	0.0011	3	86	3	45	3	45	0	0	00
0.100	0.013	60	0.088	0.0011	4	48	4	00	3	45	+	......	55
						+ 8		+ 7					
0.100	0.013	70	0.088	0.0011	4	94	4	42	3	45	+	1	04
0.150	0.013	0	0.132	0.0017	4	93	4	40	5	49	—	1	09
0.150	0.013	30	0.132	0.0017	5	45	4	86	5	49	—	—	63
0.150	0.013	50	0.132	0.0017	6	38	5	69	5	49	+	—	20
0.150	0.013	60	0.132	0.0017	6	75	6	02	5	49	+	—	53
						+ 8		+ 7					
0.150	0.013	70	0.132	0.0017	7	46	6	65	5	49	+	1	23
0.200	0.013	0	0.176	0.0021	7	38	6	58	8	26	—	1	66
0.200	0.013	30	0.176	0.0021	7	84	7	00	8	26	—	1	26
0.200	0.013	50	0.176	0.0021	8	82	7	87	8	26	—	—	39
0.200	0.013	60	0.176	0.0021	9	19	8	21	8	26	—	—	05
0.200	0.013	70	0.176	0.0021	10	02	8	94	8	26	+	—	68
0.500	0.013	0	0.440	0.0058	22	60	20	18	20	41	—	—	23
0.500	0.013	30	0.440	0.0058	23	11	20	63	20	41	—	—	22
0.500	0.013	50	0.440	0.0058	23	92	21	35	20	41	+	—	94
0.500	0.013	60	0.440	0.0058	24	25	21	65	20	41	—	1	24
0.500	0.013	70	0.440	0.0058	24	95	22	27	20	41	+	1	86
0.800	0.013	0	0.705	0.0092	37	89	33	83	33	52	+	—	31
0.800	0.013	50	0.705	0.0092	39	21	35	00	33	52	+	1	48
0.800	0.013	70	0.705	0.0092	40	23	35	89	33	52	+	2	37
1.000	0.013	0	0.881	0.0116	48	08	42	92	42	25	+	—	67
1.000	0.013	50	0.881	0.0116	49	39	44	10	42	25	+	1	85
1.000	0.013	70	0.881	0.0116	50	43	45	02	42	25	+	2	77
1.500	0.013	0	1.321	0.0174	73	56	65	67	64	50	+	1	17
1.500	0.013	50	1.321	0.0174	74	87	66	83	64	50	+	2	33
1.500	0.013	70	1.321	0.0174	75	90	67	76	64	50	+	3	26
2.000	0.013	0	1.760	0.0232	99	03	88	42	86	85	+	1	57
2.000	0.013	50	1.760	0.0232	100	35	89	59	86	85	+	2	74
2.000	0.013	70	1.760	0.0232	101	37	90	51	86	85	+	3	66

NOTE.—According to the Upper and Freiberg tariffs, gold and silver ores are only payable when total payments per Zoll-centner amount to at least 2 thaler = 3 florins Ö. W. = $1.42 gold.

II.—*Table for lead-ores.**

A.—QUARTZOSE, LEAD-ORESE.

Contents in a Vienna centner.			Contents in a Zoll-centner.			Payment according to the tariff of—						Greater or less price in comparison with the Upper Harz and Freiberg tariff.
Auriferous silver.	Contents of gold in a mint-pound of auriferous silver. (Mint-pound, 500 grams.)	Lead-contents, (Vienna pound.)	Auriferous silver.	Contents of gold in a mint-pound of auriferous silver. (Mint-pound 500 grams.)	Lead-contents, (Vienna pound.)	Schemnitz, Lower Hungary.				Fiscal works of the Upper Harz, Freiberg, &c.		
						V. centner.		Zoll-centner.		Zoll-centner.		
Mint lbs.	*Mint lbs.*		*Mintlbs.*	*Mint lbs.*		*Fl.*	*Kr.*	*Fl.*	*Kr.*	*Fl.*	*Kr.*	*Fl. kr.*
0.040	0.015	30	0.035	0.0005	30	1	17	1	4	2	20	− 1 16
0.040	0.015	40	0.035	0.0005	40	3	8	2	77	2	90	− 13
0.040	0.015	50	0.035	0.0005	50	5	5	4	51	3	60	− 91
0.040	0.015	60	0.035	0.0005	60	7	10	6	16	4	30	+ 1 86

*In table I and II the net value per "Zoll-centner" is reckoned from 5 to 10 kreutzer higher in every lot, according to the Upper Harz and Freiberg tariffs, than is actually given in payment. This surplus was kept in for reason of the silver-contents, the author not knowing whether the same is paid for, and if so how high.

B.—PYRITOUS LEAD-ORES.

0.040	0.015	30	0.035	0.0005	30	3	24	2	90	2	20	+ 70
0.040	0.015	40	0.035	0.0005	40	4	73	4	22	2	90	+ 1 32
0.040	0.015	50	0.035	0.0005	50	6	25	5	58	3	60	+ 1 98
0.040	0.015	60	0.035	0.0005	60	7	54	6	73	4	30	+ 2 43
0.030	0.040	20	0.025	0.0010	20	1	77	1	58	1	43	+ 15
0.030	0.040	40	0.025	0.0010	40	4	68	4	18	2	97	+ 1 21
0.030	0.040	60	0.025	0.0010	60	7	71	6	89	4	38	+ 2 51
0.040	0.060	20	0.033	0.0021	20	2	95	2	63	2	25	+ 38
0.040	0.060	40	0.033	0.0021	40	5	86	5	24	3	78	+ 1 45
0.040	0.060	60	0.033	0.0021	60	7	89	7	4	5	14	+ 1 90
0.050	0.080	20	0.041	0.0035	20	4	38	3	91	3	37	+ 54
0.050	0.080	40	0.041	0.0035	40	7	36	6	57	4	90	+ 1 67
0.050	0.080	60	0.041	0.0035	60	10	32	9	22	6	31	+ 2 91
0.100	0.100	20	0.080	0.0089	20	10	1	8	94	8	33	+ 61
0.100	0.100	40	0.080	0.0089	40	12	92	11	53	9	86	+ 1 67
0.100	0.100	60	0.080	0.0089	60	15	95	14	24	11	29	+ 3 00

NOTE.—According to the Upper Harz and Freiberg tariffs, lead-ores are only bought when their value amounts to 2 thaler = 3 florins Ö. W. = $1.42 per hundred-weight.

As can be seen by the comparison, the payment of auriferous silver and lead-ores is, in general, better according to the Schemnitz tariff than the Freiberg tariff, &c., from which we can draw the conclusion that the smelting-costs are, on an average, lower at the Lower Hungarian works than at Freiberg or in the Upper Harz, when judged from the tariffs.

469. E. CHANGES IN THE LOWER HUNGARIAN METALLURGICAL PROCESSES.—Though the Lower Hungarian metallurgical works, up to the year 1873, have good results to show in comparison with other works of similar character, still the continually-increasing price of fuel, especially of charcoal and wood, and the large administration-costs of the separate works, made a complete change in the metallurgical process absolutely necessary. Above everything else, it was determined to consolidate all the lead and silver smelting-works into one, and the Schemnitzer Hütte, being the most central, was chosen for that purpose.

The Neusohler Hütte was given up at the beginning of this year, and the Zsarnowiczer Hütte is to be given up toward the close of same.

The smelting-operations will be so conducted that large amounts can be smelted at once, and so treated by preliminary processes that the ingredients contained in the ores that are of disadvantage to the smelting-operations, such as sulphur and zinc, will be turned to profit. The Freiberg smelting-works were chosen as a model in the erection of the works.

The Fortschaufelungs-Röstöfen (long reverberatory roasting-furnaces) have been in operation since March, 1873. The length of the hearth is 52 feet by 8 feet wide, and they give very satisfactory results. During the first roasting experiments in these furnaces wood was used as fuel; afterward bituminous coal was made use of for the continual work.

The smelting will be conducted in round blast-furnaces of the Pilz pattern with eight tuyeres; the one already erected has a small "sumpf." The gases escape by a canal in the side of the furnace, through a chimney 30 feet high. Coke will be used as fuel in the new furnace.

The experiments to be made upon the production of zinc will first be made with the blendic-pyritous slimes; the same will be roasted, and, by lixiviating with water, zinc-vitriol will be produced.

As all the Schemnitz lead-ores carry more or less zinc, the mines are to be compelled, in dressing their ores, to separate them into those rich and poor in zinc. In order that such a separation, which is of great importance to the smelting-manipulations, shall be carried into effect, the smelting-works are to determine upon what amount of zinc contained in an ore shall receive payment therefor, and how the smelting-costs of the ores rich in zinc are to compare with those poor in that metal.

Up to the present time there has been no difference made in the tariff upon the smelting-costs of ores containing an equal percentage of lead, whether the same carry 10 per cent. or 30 per cent. of zinc.

At the St. Michaelistollner mine almost perfectly pure zinc-blende was obtained in dressing the blendic lead-ores.

According to analysis made by the author, the same contained:

$Si\,O_3$	4.650
Fe	2.625
Ca O	1.600
Pb	1.330
Cu	0.150
Zn	59.399
Au. Ag	0.008
S	30.533

The construction of a sulphuric-acid manufactory could not be undertaken, as the financial "ministerium" has not as yet granted the necessary money. It is desirable that this want should be made known as soon as possible, for it is to the interest of the government, as well as the private mines, and would also be of advantage to the smelting-works, that a source of revenue should be made of the manufacture of the sulphur contained in the ores into sulphuric acid.

From the ores at our disposal, there could be produced over 60,000 cwt. of sulphuric acid yearly.

By means of smelting large amounts of ore and the use of coke and bituminous coal, the smelting costs will fall much behind those of former times.

There is, therefore, a possibility, in consequence of the diminished administration and smelting costs, and, further, by the turning to account of the sulphur and zinc, that the ore-tariff can be made of such advantage on the part of the mining interests, that even products, which at present must first be concentrated by wet-dressing, in order to reach the demanded percentage of metal, can be sold with profit.

As now the railroad, which was built by "Montan-Aerar," runs directly to the smelting-works, it will be possible for distant mines of Hungary, and even foreign mines, to send and sell their ores to the Chemnitz works, especially as the works, according to section 22 of the purchase tariff, have no use of the same, the net profits of the works for each year being divided among the sellers of ore in proportion to the amount delivered by each. Metallurgical products, such as argentiferous matte, &c., are purchased according to the same rules and regulations.

470. SURVEY OF THE METALLURGICAL PROCESSES A AND B.—A. At the lead and silver smelting-works Schemnitzer, Zsarnoviczer, Kemnitzer, Neusholer, and the Mutual Dillner Hütte.

Mining products: a. Auriferous-argentiferous-pyritous slimes; *b.* auriferous-argentiferous slimes; *c.* Gold and silver ores, raw-ores, enriching-ores, and lump-ore; *d.* Auriferous-argentiferous lead-ores and slimes; *e.* Auriferous-argentiferous lead-copper-ores and pyritous slimes.

Products: f. Cupels; *g.* dross-slimes; *h.* different industrial products.

Fluxing material: i. Flux-pyrites, limestone, iron, and slag from its own manipulation.

I. SMELTING FOR MATTE.

Smelted:	*a.* Pyritous slimes.	*b.* Silver-slimes.	*c.* Raw ores.	*g.* Sweepings;	*i.* Flux, pyrites.	2. Furnace-dross.
Produced:	1. Raw matte. 2. Furnace-dross.					

II. MANIPULATIONS OF "REICHVERBLEIUNG."

1. PRELIMINARY OPERATIONS.

A.—Roasting in reverberatory furnaces.			*A.—Roasting in heaps.*			
b. Silver-slimes.	*d.* Lead-ores and slimes.	*e.* Copper-ores and pyritous slimes.	1. Raw matte.	7. Lead-matte.	10. Matte-matte.	8. Sweepings.
4. Roasted lead, roasting charge. 5. Fumes.			Roasted products as above.			

2.—CHIEF MANIPULATIONS.

B.—"Reichverblei" smelting.

4. Roasted lead, roasting charge.	1. Raw matte.	*c.* Enriching ores.	17. Litharge.	18. Test and "*abstrich.*"	7. Lead-matte.	8. Dross.
b. Rich lead. 7. Lead-matte. 8. Furnace-dross.						

3.—Finishing manipulations.

C.—Matte-smelting.	*D.—Matte-resmelting.*
7. Roasted lead-matte; *e.* Copper-ore; 17. Litharge; 18. Test "*abstrich;*" 19. Furnace-dross; 23. Carcass, ("*Kienstöcke.*")	10. Matte, roasted matte; 17. Litharge; 18. Test "*abstrich;*" 15. Furnace-dross.
9. Matte-lead; 10. Matte-matte; 11. Furnace-accretions, sweepings.	13. Matte-matte lead; 14. Copper-matte; 11. Furnace-dross, sweepings.

III.—CUPELLATION.	IV.—LIQUATION.
6. Rich lead; 9. Matte-lead; 13. Matte-matte lead; *c.* lump-ore.	19. Lead from litharge.
17. Manipulation-litharge; 18. Test "*abstrich;*" 19. Litharge-lead; 20. Blick-silver; 21. Red and green commercial litharge.	20. Commercial lead; 23. "*Kienstöcke.*"

AT THE COPPER-SMELTING WORKS.

Smelting-works: Altgebirg and Tajowa.

Mining products: Argentiferous copper-ores, non-argentiferous copper-ores, mine cement slimes.

Other products: Mint-cement copper, copper-scales, copper-matte from silver-smelting works, "Matreier" cement-copper.

Fluxing and other material: Limestone, salt, slag, salt-solution, hot water, iron, and copper.

I.—Smelting of argentiferous matte.	II.—Resmelting of argentiferous matte.
a. Argentiferous copper-ore; 3. Raw sweepings.	Roasted raw-matte. 5. "*Ober*" matte. 6. Dross. 2. Unliquated speiss. *a.* Argentiferous copper-ores.
1. Raw-matte. 2. Speiss. 3. Raw sweepings.	4. Black copper. 5. "*Ober*" matte. 6. Dross.

III.—Resmelting of roasted lead products.

Roasted; *b.* Matte from silver-works. 2. Speiss. 8. "*Ober*" matte. 9. Dross. *a.* Argentiferous copper-ores.

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7. Black copper. 8. *Ober* matte. 9. Dross.

IV.—Extraction of silver from black copper.

A.—Roasting with salt.	*B.—Lixiviation with cold solution of salt.*
47. Black copper. *d,* 20. Cement-copper. 11. Roasted kernels.	10. Roasted black copper-powder. 14. Rich residues.
10. Roasted black copper-powder. 11. Kernels.	Rich solution, poor solution, rich residues, extraction residues.

C.—Washing with hot water.	*D.—Precipitation with copper.*
15. Extraction residues.	12. Rich solution. 30. Granulated copper.
16. Wash-water. 17. Residues.	18. Extra silver. 30. Granulated copper. 19. Copper solution.

E.--Precipitation of copper with iron.

19. Copper solution. 13. Poor solution. 16. Wash-water.

20. Cement-copper. 21. Manipulation solution.

V.—REDUCTION OF RESIDUES.

17. Residues. 26. Dross-copper. 27. Unliquated non-argentiferous matte. *c.* Mine-cement slimes. 31. Refining dross. *e.* Copper scales.

22. Reduction copper. 23. Dross. 24. Matte. 25. "*Abstrich.*"

VI.—SMELTING OF NON-ARGENTIFEROUS DROSS.

23. Dross. 24. Matte. 25. "*Abstrich.*" *e.* Copper scales. 28. Sweepings from copper hammer. *b.* Non-argentiferous copper-ore. 31. Dross. 32. Test-bottom.

33. Crucible dross. 26. Dross copper. 27. Non-argentiferous matte. 28. Furnace-dross.

VII.—REFINING.

26. Dross-copper. 22. Reduction-copper. *g*, M. cement-copper. *e.* Copper scales.

29. Refined copper. 30. Kernel copper. 31. Dross. 32. Hearth. 33. Crucible dross.

471. UPPER HUNGARY.—The Upper Hungarian "Wald Bürgerschaft Schmelz and Amalgamir werke" and the Phœnix Hütte were represented by a complete collection of their ores, intermediate and final products, which will serve to illustrate the different manipulations: copper-ore, carrying mercury and silver, (tetrahedrite,) argentiferous quartzose, and gelferze, and non-argentiferous copper-ores.

From the silver, copper, and quicksilver process.

Matte, roasted matte, oberlech speiss, slag from ore and matte smelting, antimonial speiss, black and granulated copper, silver amalgam, cement-silver, silver bricks, and mercury.

From the copper process.

Matte, roasted matte, upper matte, slag from ore, matte, and black copper-smelting; refined copper and manufactured articles, kettles, tuyeres, &c.

472. These two works, and also a third, the "Georgshütte," belong to the private companies who own the mines in the Schmöllnitz district. Non-argentiferous copper-ores, exclusively, are reduced at the Phœnix Smelting-Works; but all kinds of copper-ores are treated at the other two works. The processes are at all three works the same, where ores of a corresponding nature are treated.

The argentiferous ores contain from 0.06 to 0.07 per cent. = 17 oz. 9 dwt. 19 gr. to 20 oz. 8 dwt. 9 gr. silver, and 10 per cent. copper. The non-argentiferous copper-ores from 4.5 to 5 per cent. copper. The utilization of the ores carrying copper, silver, and quicksilver is performed in three principal operations.

473. *a.* The quicksilver-distillation.* This is conducted in round

* Free use is here made of a portion of the work entitled "*Beschreibung einiger wichtigerer Metallbergbaue in Oberungarn,*" by Gustav Fuller.

bins, which are about 20 feet in diameter, and surrounded with a low stone wall; a shaft made of pieces of wood is erected in the middle and filled with charcoal. This is used to light the fuel, and, after the fire is started, to preserve a draught during the continuation of the roasting. When the bins are to be charged, a thin layer of finely-crushed ore is spread on the bottom; upon this wood is first placed, and then a small quantity of charcoal. The ore, that has already served for a covering and condensing-medium, is laid about 6 inches thick upon the fuel. The richer and larger pieces of ore are then charged, and the poorer come on top. The upper part of the heap is kept cool by throwing fresh quantities of ore on the places that become warm. When the ore has been roasted and cooled, which operation lasts about three to four weeks, the quicksilver is found condensed and scattered throughout the upper layers. It is obtained by repeated washing in sieves and purified by distillation.

474. *b.* The residue from the quicksilver is smelted in shaft-furnaces 19 feet high. The charge is 50 cwt. residue from amalgamation, 50 cwt. unroasted non-argentiferous copper-ore, 5 cwt. pyritous ore, 20 cwt. quartz, 16 cwt. slag from matte-smelting, and 520 cubic feet charcoal.

The products are matte, speiss, and slag. The speiss contains 0.2 per cent. = 58 oz. 6 dwt. silver, and 28 per cent. copper. The silver is extracted by amalgamation, and the residue is smelted for speiss, which is sold, and copper-matte, from which an inferior grade of copper is produced. The matte is crushed and roasted in free heaps about twelve to thirteen times. The roasted matte is smelted for black copper in shaft-furnaces 14 feet high. The charge is composed of: 100 cwt. roasted matte, 15 to 20 cwt. quartz, and 550 cubic feet charcoal.

The black-copper, containing 0.35 per cent. = 102 oz. silver, and 82 per cent. copper, runs, when tapped, into a water-basin, and is granulated. It is then roasted, and the silver extracted by amalgamation.

The matte from the black-copper smelting, assaying 0.07 to 0.175 per cent. = 20 oz. 8 dwt. to 50 oz. 19 dwt., and 50 to 60 per cent. copper, is added to the raw matte after the fourth roasting, and is smelted with that for black-copper, &c. The slag is smelted with roasted argentiferous copper-ore.

475. *c.* The non-argentiferous ore is roasted and smelted with slag and quartz. The resulting matte is roasted, and then smelted in a shaft-furnace, with the following charge: 100 per cent. roasted matte, 312 per cent. amalgamation-residue, 50 per cent. quartz. The consumption of charcoal is 470 cubic feet to 148 cwt. of charge. The result is slag, matte, and raw copper. The matte is roasted with the matte from ore-smelting. The slag smelted with non-argentiferous roasted ore, and the raw copper is refined, producing commercial copper.

476. These three smelting-works have twelve shaft-furnaces, five reverberatory furnaces, two small Hungarian reverberatory furnaces, with two hearths and amalgamation-apparatus. The annual produc-

tion has greatly decreased in the last few years. It was, in 1871, copper, 494,000 kilograms; silver, 1,025 kilograms; quicksilver, 17,640 kilograms.

477. TRANSYLVANIA.—ZALATHNA.—There was an interesting display of statistical charts, ores, and products from the smelting-works at Zalathna, among which were the following: Silver, gold, and lead ores; copper-matte, black-copper, slag, cement-silver, gold, and silver. A piece of cupellation-hearth, on which lead containing gold and silver had been cupelled, was exhibited. In this there were several cavities, in which were large and small buttons, having the color of almost pure gold.

478. The smelting-works at Csertester and at Zalathna were erected in 1740 to 1750, and are both worked by the government. They have two large, four small, and two low shaft-furnaces; two cupellation-furnaces; two copper-refining furnaces; and an amalgamation-apparatus.

479. A new process has lately been introduced at Zalathna, by which it is stated a great saving in the treatment of the ores will be effected. The ores* containing gold and tellurium are first roasted, and then smelted, whereby a raw matte is obtained. The matte is granulated and treated with dilute sulphuric acid, which is heated by steam. The residue, containing lead, silver, copper, and gold, is smelted with lead-flux, and the silver-lead produced is cupelled. Ores rich in tellurium and also the fumes from the preceding roasting are first treated with dilute hydrochloric acid, and then with concentrated sulphuric acid. Tellurium is precipitated with metallic zinc. It is then washed and dried, when it is melted in a porcelain crucible. The tellurium contains antimony, arsenic, copper, and lead. From one hundred and sixteen pounds of ore two pounds of tellurium are produced.

480. These works produce annually: Gold, 288.96 kilograms; silver, 619.92 kilograms; copper, 19,992 kilograms.

481. There were also a collection of ores and a few metallurgical products and drawings exhibited from the "Sicbruburger Kupfergewerkschaft." The copper ore is reduced by roasting, smelting for matte; and then, after roasting, smelting for black copper; which is refined, either producing rosette copper or copper ingots. The works own four large shaft-furnaces and one refining-furnace. The amount of copper produced annually is valued at 120,000 to 160,000 florins.

482. NAGY BÁNYA.—A large and systematic collection of geological charts and specimens of rock and minerals were exhibited by the United Smelting-Works of Nagy Bánya. The three principal works are:

Verespatek, represented by gold and tellurium ores and products of amalgamation, which process is practiced for the extraction of gold. The value of the annual production of gold and tellurium averages 35,750 florins.

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* The description of this process is from the official report of the "*Central commisson des deutschen Reiches*," and thus appeared in the *Berg- und Hüttenmännische Zeitung*, 1874, p. 181.

The Felso Bánya Copper-Works displayed several samples of manufactured copper articles.

The Fernezely Silver, Gold, and Lead Works exhibited charts of production, ores, product of the humid silver-extraction process, litharge, and soft lead.

483. The process of extracting gold and silver from roasted ore was introduced by Kiss in 1859. It consists in a preliminary chloridizing roasting, after which the copper chloride is extracted with cold water and the chlorides of silver and gold with $Ca\,O\,S_2\,O_2$. Copper is precipitated by iron, the gold and silver with calcium sulphide.

484. Zinc-desilverization was introduced in Fernezely in the beginning of 1873, these being the second works in the Austrian-Hungarian Empire at which this process is practiced.

The average annual production of the works at Fernezely, Verespatek, and Felso Bánya is: gold, 435.5 kilograms; silver, 6,813 kilograms; copper, 93,576 kilograms; lead, 740,656 kilograms.

485. GALICIA.—The zinc-metal industry of Galicia was represented by the reduction-works of A. M. O. Potockie Siersza, near Krackau, who exhibited zinc-ores, calamine and blende, cadmium, raw and refined zinc; also a model of a zinc distillation-furnace, with a gas-generating furnace attached.

CHAPTER X.

RUSSIAN EXHIBITS.

Exhibit of smelting-works at Nijni-Tagnil; Ores treated, furnaces employed, fuel; Refining the black copper; Exhibits of Bogolorsk, Jongor, Verkh-Issetsk, Kedaberg, Paulina Zinc-Works.

486. The display of mineral and metallurgical products was small, owing to the difficulty of transportation, but the articles exhibited were interesting, and the quality did justice to Russia's well-earned reputation.

487. The copper-works of Prince Paul Demidoff, located at Nijni-Tagnil, in the Verkhatourie district, in the Ural Mountains, were represented by an incomplete collection of copper ores and products. The ores were composed of copper and iron pyrites and copper carbonates. The products were slag from ore-smelting, matte, black and refined copper; the latter was of a light-rose color, and had a remarkably distinct crystalline structure.

488. The copper-works at Nijni-Tagnil,* founded in 1725, are the most important in the Ural Mountains, and produce almost 40 per cent. of Russia's total production of refined copper, and 65 per cent. of the total production of sheet-copper. The richest ores treated are the Siberian, containing as high as 16 per cent. copper, the ores from the Altai 9 per cent., the Ural ores 4 per cent., and the ores from the Kasan district with seldom 2 per cent. copper. They are, with very few exceptions, easily reducible.

489. When smelting arsenical ores, a small quantity of black copper is produced, the object of which is to concentrate the arsenic in the black copper, in order to obtain a purer matte. Smelting is conducted partly in the old Swedish furnaces, partly in furnaces which are semicircular in horizontal section, and having generally ten tuyeres, but principally in Rachette furnaces with blast heated to about 100° C. They have been modified by Skindar, who gave them an oval shape in horizontal section. The latter furnaces make campaigns of several months, and give general satisfaction.

490. Formerly 100 pounds of charcoal were calculated to carry 400 pounds of charge in smelting ore; at present 100 pounds of charcoal carries 414 to 420 pounds charge in the ore-smelting, and 437.5 to 450.5 pounds charge in the matte-smelting. The percentage of copper in the slag from ore-smelting is also more favorable; formerly it was 0.25 to 50

* The description of copper-smelting is from "*Russland's Montan Industrie*," and *Einer Bereisung der vorzüglichsten Hüttenwerken des Urals im Jahre*, 1870, by P. V. Turner.

per cent., but it is now only 0.25 to 30 per cent. If we compare the quantity of fuel consumed in smelting copper at other places with that in Nijni-Tagnil, we will perceive that very successful results have been obtained at the latter place. In Åtridaberg, in Sweden, 100 pounds of charcoal carry 312 pounds charge. In England, where the operation is performed in a reverberatory furnace, with bituminous coal as fuel, 100 pounds of coal is calculated to smelt 225 pounds charge, producing slag with 0.50 per cent. copper. Although it is impossible to compare exactly the effect of charcoal and bituminous coal, it is an important fact, that the slag-dumps at Nijni-Tagnil contain only about half as much copper as those in Wales.

491. The black copper is refined partly in refining-hearths and partly in English reverberatory furnaces. A comparison of the two shows the latter method to be the more advantageous both in regard to a saving in fuel and metal. In the refining-hearth 1½ cubic feet (English) of ore and 6 cubic feet charcoal are consumed in the production of 100 pounds refined copper, with a loss of 16.5 per cent.; while the consumption of fuel per 100 pounds refined copper in the English furnaces is 5.1 to 5.3 cubic feet of split wood, and the loss of copper is 13.9 to 15.4 per cent.

492. The copper-works at Nijni-Tagnil produced, in 1872, 1,501,026.44 kilograms of refined copper. In addition to the above the following small displays of copper products from the Ural Mountains were made:

493. The copper-works of Bogolovsk in the district of Verkhatourie, government of Perm, were represented by samples of ores, matte, and refined copper. These works produce annually 196,560 kilograms of refined copper.

494. The works at Jougoo, in the government of Perm, exhibited copper pyrites, malachite, and refined copper. They were founded in 1757. Their annual production is 163,800 kilograms of refined copper.

495. Mme. de Stanbock-Fernor exhibited copper pyrites and malachite from her copper-works at Verkh-Issetsk, in the government of Perm. The works were founded in 1773, and produced annually 278,460 kilograms of refined copper.

496. The copper-works at Kadaberg, in the Caucasian Mountains, were represented by a few metallurgical products, viz, slag, matte, and refined copper.

497. The Paulina Zinc-Works, owned by M. G. de Kramsta, located in the government of Piatrkow, in the Bendian district, Poland, made a very interesting exhibit of drawings, showing the situation of the zinc-works and the plans according to which they were erected; the furnaces were also described by elaborate drawings. They are muffle-furnaces, with gas-generating furnaces attached. The ores were blende, calamine, galena, and cerusite. The lead-ores are sent to Prussia for reduction, the zinc-ores alone being reduced at these works. The production of zinc in 1871 was 1,342,707.88 kilograms. This amount exceeds one-half of Russia's total zinc production. These zinc-works have been in operation since the commencement of the present century.

CHAPTER XI.

TURKISH EXHIBITS.

EXHIBITS OF TURKEY; CONDITION OF METAL INDUSTRY; SMELTING PROCESS.

498. There was only a small exhibit of metallic minerals from Turkey, and even then it was with difficulty that the names of the owners or the localities whence they came could be ascertained. Noticeable were galena ores from the district of Kourouk and Salonique, in Turkey in Asia; lead from the department of the Dardanelles; copper-ores from the departments of Aleppo and Sivas; copper from the department of Diarbekir, exhibited by M. Theodori.

499. We are informed that the mineral resources of Turkey are very extensive, but however that may be, it is still true that this, as well as many other branches of industry in that country, is still in its infancy. We shall here make use of a report made by Herr W. Fishback, a German engineer, who is employed by the Ottoman government. It appeared in the "*Berg- und Hüttenmannische Zeitung*" in 1873, p. 109. Lead and silver were extracted in Turkey by the ancients; they worked the outcroppings, and sank shafts down to the water-level only, for, strange as it may seem, they had not learned the use of adits. The richest lead and silver mines are in Cratova, near the river Egridéré, near Nevrokop and Serres, in Macedonia, near Ghümüschané, Bulgarmaden, Cosan in Syria, and in Asia. Copper was extracted many centuries ago in Asia. It is found in several localities. Herr Fishback discovered, in 1872, on the surface, an unusually rich occurrence of copper-ore, (copper glance,) but does not inform us as to its extent.

The ore-veins (argentiferous galena) run from north to south; they have a regular dip and a permanent thickness. The ores are only separated imperfectly from the associated minerals by hand. Small quantities of iron pyrites sometimes accompany the galena, and very seldom blende. The ore is but partially roasted in large heaps surrounded by walls.

500. The smelting is conducted in low shaft-furnaces, with a low pressure of blast. Charcoal serves as fuel. The manner and relative proportion of charging ore, flux, and fuel, is improvised by the workmen, who lack all experience. Silver-lead has been cupelled until recently in flat-bottomed open hearths, made of wood-ashes. The heat was pro-

duced by throwing burning trunks of trees on the lead. But it must at present be sent to the mint at Constantinople for desilverization.

The bad condition of the furnaces, together with the very uncertain order in which ore, flux, and fuel are charged, lead to great metallic losses through volatilization, slagging, and the formation of salamanders. The mining and smelting operations in Asiatic Turkey have been lately pushed with energy, and we may expect at least a large increase in the production of bullion.

CHAPTER XII.

GRECIAN EXHIBITS.

Exhibits of Greek Commission Central; From Attica; Results of ancient metallurgical operations; Operations of the French-Italian Company; Lead earth—Theories on undeveloped metallic resources; Result of recent prospecting.

501. The "Greek Commission Central" displayed an unsystematic collection of ores, and failed to name the localities where they were found. I observed, as the metallic minerals, (excluding iron,) copper pyrites, copper carbonate, galena, and cerusite.

502. Attica was the only Greek district represented at the Exposition by lead-ores and lead. The Greek Metallurgical Stock Company of Attica exhibited a collection of minerals, among which were lead and copper.

The metallurgical company, "Antiparos," of Attica, exhibited galena and silver-lead. Silver-lead from Attica was also exhibited by M. A. Kordellas.

503. The origin and former success of mining and smelting in Greece is a matter of political as well as of mining history. It was from the argentiferous lead-ores occurring in Laurion that the ancient Greeks derived their principal revenue. There were at one time as many as 20,000 slaves employed in the mines and smelting-works* in that place. The imperfect dressing and smelting methods of the ancients, together with the large percentage of blende contained in the ores, were the causes of the richness of the immense slag-dumps and large amount of tailings which have lately been the occasion of so much dispute between a French and Italian smelting company and the Greek government. Herr Fiedler, a German mining engineer, was commissioned by the Greek government in 1837–'39 to inspect and report upon the mineral resources of Greece. Upon the completion of his travels, he published a work—"*Reise durch alle Theile des Königreichs Griechenland*," Dresden, 1840—in which he spoke very unfavorably concerning the prospects of recommencing lead-mining operations and the extraction of lead from the remains of the ancient mining and smelting operations in Laurion. This probably induced the Greek government to make a contract with a French-Italian company, conceding to them the right of extracting

* Free use is here made of a portion of a communication by Herr Baldauf to the *Berg- und Hüttenmannische Zeitung*, 1871, Nos. 37 and 38.

silver and lead from the intermediate products of the ancient smelting-operations. The Greek government now claims that the contract only included the old slags. The royalty paid by the company was $4.24 currency per ton of lead produced. This would make the indemnity for 10,000 tons, the amount extracted in 1870, equal to $31,460 currency. Although these slags, or at least a part of them, were resmelted a few centuries after the period of the successful working of the mines, they still contain considerable quantities of silver and lead. They average from 6 to 13 per cent. of lead, 0.004 per cent. = 1 oz. 3 dwt. 7.68 gr. silver, 6 to 10 per cent. zinc, and 4 to 6 per cent. of antimony. The amount of slag remaining has been estimated at 1,200,000 tons.

504. The above-named French-Italian company erected, at a large outlay, in 1865, extensive smelting-works at Eugastyria, located on the east coast of Attica, a place where smelting-works, in all probability, formerly existed. From the works streets have been built in all directions to the old slag-dumps. The slag is first freed from the stones, and then transported to the works in two-wheeled wagons.

In 1870, fifteen low (*Halbhohoefen*) Castilian cylindric furnaces were built, and ten to twelve kept constantly in operation. They are constructed with mica-schist, and have three tuyeres. The diameter of blast-nozzle is 11 centimeters, and the pressure of blast is 8 to 12 centimeters, water-column. The slag is smelted with 16 to 17 per cent. coke and a large quantity of lime. Forty tons of silver-lead, assaying 0.04 per cent. =11 oz. 13 dwt. 4.8 gr. silver-ore, produced daily. From 75 to 88 per cent. of the 6 to 13 per cent. lead contained in the slag is extracted; the remainder is either caught in the condensation-chambers, or goes in the slag, in which case it is lost. The silver-lead is refined in large reverberatory-furnaces, is marked "φος" and exported to England for desilverization.

505. The so-called "lead-earth," designated by the ancients "*Εμβολάδες*" was the subject of protracted controversy between the Greek government and the foreign smelting company. The question in dispute was whether the "lead-earth" was extracted from the mines by the ancients only in order to gain room for further working the ore-deposits, and after having been extracted, not considered worth reducing, or if it was only the residue of an imperfectly conducted dressing method. A fact that argues against the latter theory is, that the larger heaps of "lead-earth" are found where it is hardly possible that a sufficiently large quantity of water was to be had for dressing purposes. The smaller heaps are found in old shafts. Here it is possible that the rain has caused a small washing process to take place. Professor Fritzsche, of the Royal Saxon School of Mines, has made a determination of this "lead-earth," and found it to be composed of the following minerals: Lead-sulphate, principally causing and governing the lead-contents; galena, very little; copper pyrites; a mineral resembling malachite; yellow blende; quartz; white mica; iron sesquioxide, containg sulphuric acid, and other

earthy minerals. The composition of this "lead-earth" and its large percentage of quartz points to the conclusion that it once constituted the mica-slate, forming the slicken-sides of the ore-deposit; further, that the metallic minerals were contained in the mica-slate as impregnations. The theory is a very plausible one, that these ores were not considered worth further treatment upon extraction from the mines, and were, therefore, thrown from the mines. Exposure to the weather caused chemical changes in many cases, a stratification, and a universal physical change, until it assumed the nature of fine, easily-powdered earth. The commission appointed by the Greek government to examine and report upon this disputed point was composed entirely of non-professional men, and the supposition is not an unnatural one that the discovered fact that the total amount of "lead-earth" in this and other districts amounted to 6,700,000 tons, assaying from 1.5 to 11 per cent. lead, presenting a general average of 4.4 per cent. lead and 0.011 per cent. = 3 oz. 4 dwt. silver, had more weight in influencing the decision of the easily-excitable Greeks, than any scientific points which they did not understand. According to their calculation, which is undoubtedly too low, when the condition of the "lead-earth" is considered, the loss would only be 5 per cent. in dressing, and 2 per cent. in reduction of the whole amount of lead; consequently, the gain would be $25,022,450 currency. From this it is at least apparent that the value of the "lead-earth" far surpasses that of the slag, which will only give about $5,790,000 currency clear profit.

506. In regard to the unworked and undiscovered metallic resources of Greece, different opinions have been expressed. It is, however, possible that there are many important lead-deposits still unknown. An argument for this supposition is, that nearly all the Greek islands possess the same geological formation as that in Laurion, which is that of metamorphic schists, with interstratified deposits of crystalline limestone. Lead-deposits have been discovered on the islands Zea, Makronisi, and especially promising veins on Antiparos, where the surrounding rock is micaceous slate. They have a strike of about 70° to 80°, and a very steep pitch to the south. The veins are composed chiefly of galena and quartz, and contain from 35 to 65 per cent. lead, and 0.015 to 0.03 = 4 oz. 7 dwt. 8 gr. to 8 oz. 14 dwt. 19.2 gr. silver. In Karistos, in the southern part of Euböa, the island was believed by the ancients to be rich in metals. There are also veins in micaceous slate, bearing galena, quartz, and iron pyrites. The vein mass assays 15 to 40 per cent. lead, and 0.01 to 0.025 per cent. = 2 oz. 18 dwt. 4.8 gr. to 5 oz. 7 dwt. 17.2 gr. silver. Old lead-matte, found in this locality, assayed 50 per cent. lead and 2 per cent. copper. Copper has been discovered on this island, but no efforts have as yet been made to mine it.

507. By recent prospecting there have been very promising masses of galena discovered on the island of Seraphos. They are accompanied

by "lead-earth," similar to that in Laurion; the latter contains 4.5 per cent. lead and 5 oz. 16 dwt. 14 gr. silver.

Paying deposits of copper have been discovered near Lamia, (Zeitumi,) in the northern part of Greece. But as the owner of the property has no capital to prosecute mining-operations, and foreign capitalists are loth to invest, as the district borders upon Turkey, whence robber bands make periodical raids, these deposits remain in an undeveloped condition.

MANSFIELD COPPER-FURNACE.

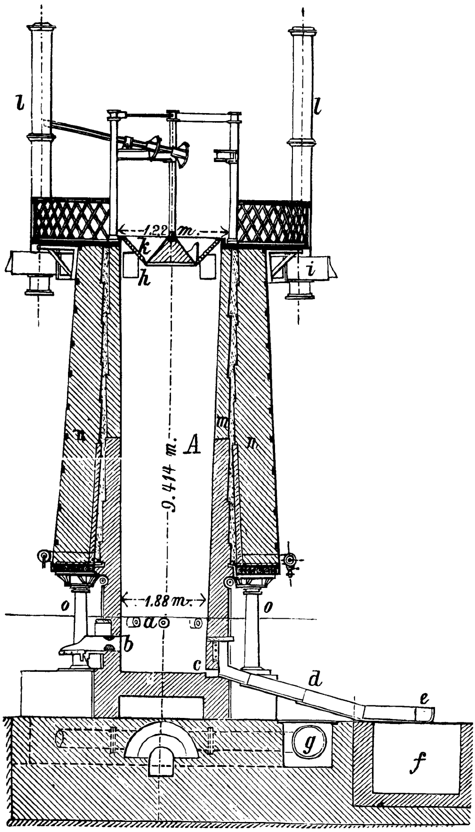


FIG. I.—Vertical section.

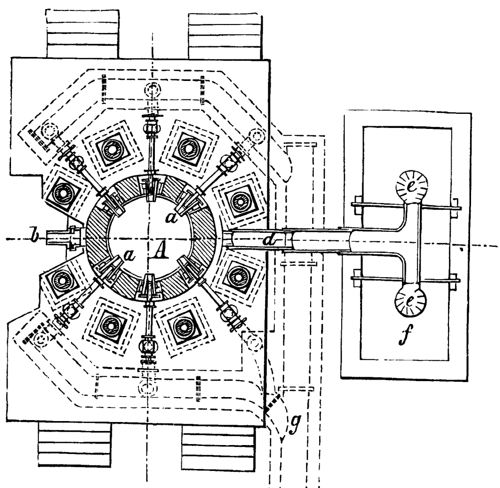


FIG. II.—Horizontal section at tuyeres.

HASENCLEVER HELBIG'S ROASTING-FURNACE AT STOLBERG.

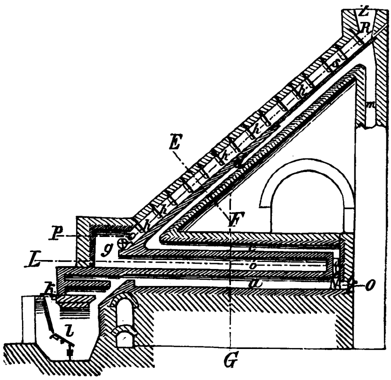


FIG. III.—Vertical section on line H K.

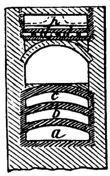


FIG. IV.—Section on line E F G.

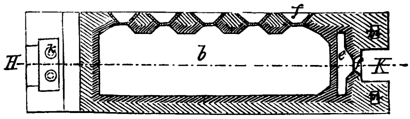


FIG. V.—Horizontal section on L M N O.

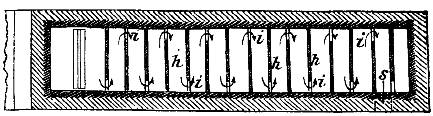
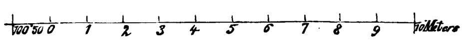
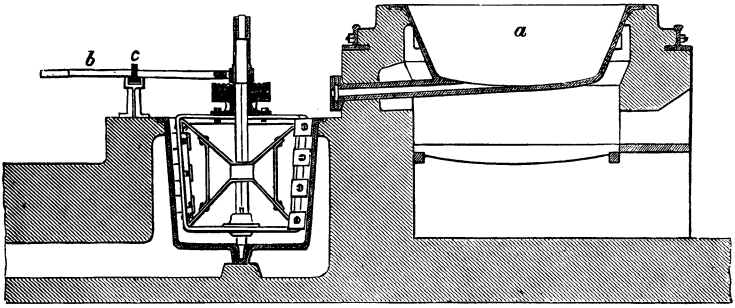


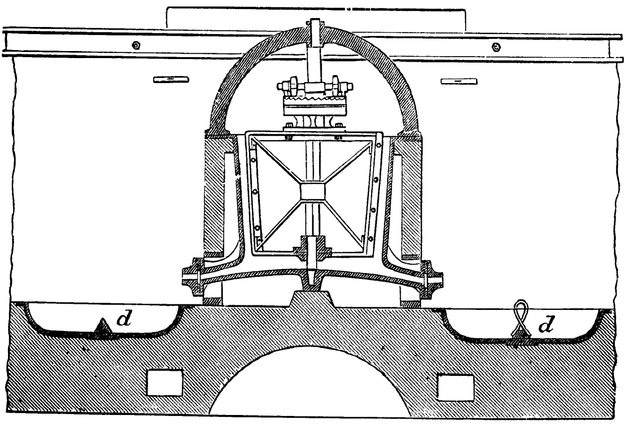
FIG. VI.—Section on line P Q R.



Scale of Figs. III to V.



Vertical section on line A B Fig. VII.



Vertical section on line C D Fig. VIII.

Fig. VII.—Battery for mechanical pattinsonizing.

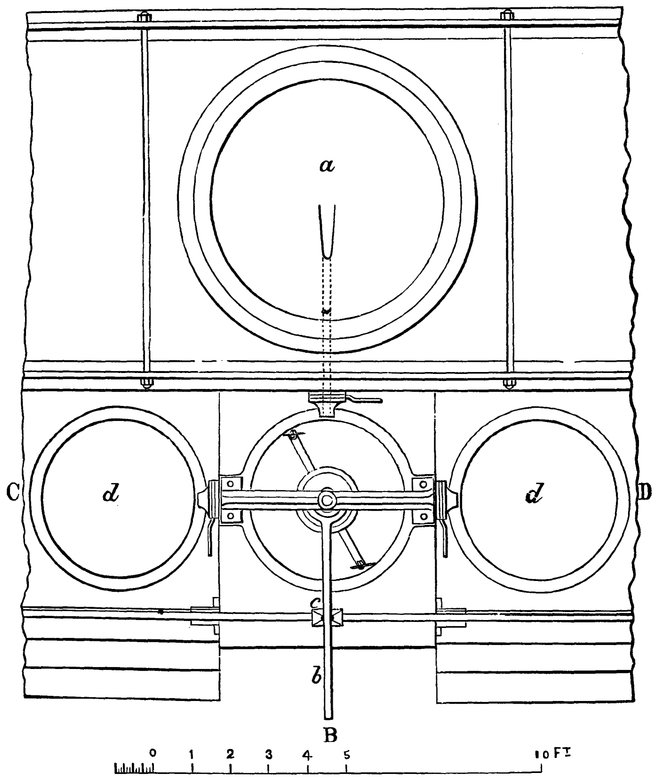
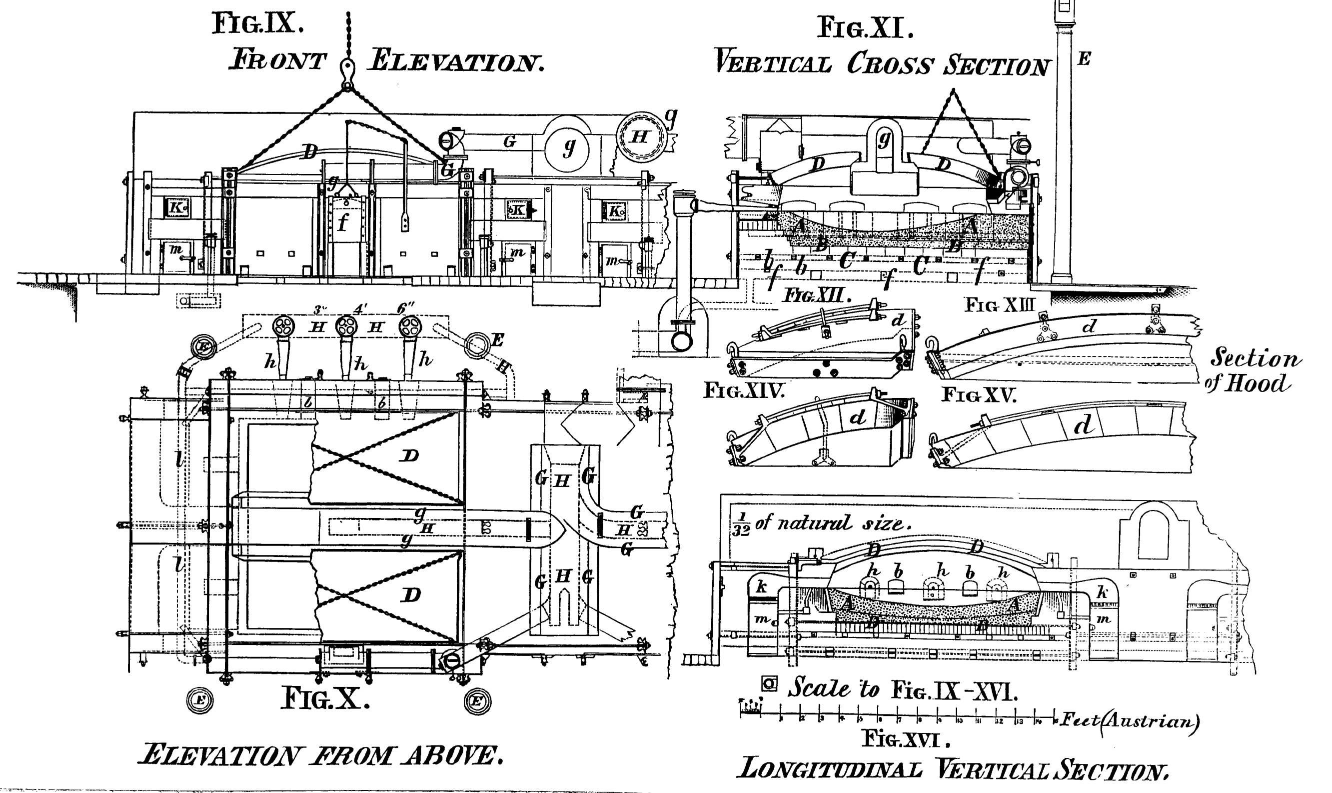


FIG. VIII.—Battery for mechanical pattinsonizing.—Plan.

NEW CUPELLATION FURNACE.—PRIBRAM, 1872.



APPENDIX A.

THE PRODUCTION OF LEAD, SILVER, COPPER, AND ZINC IN THE PRINCIPAL COUNTRIES OF THE WORLD.

Countries.	Lead.		Silver.		Copper.		Zinc.	
	Value.	Kilo.	Value.	Kilo.	Value.	Kilo.	Value.	Kilo.
United States, 1870	3,499,183 dollars	21, 515, 000	7,568,942 dollars		11,684,123 dollars		1,167,947 dollars	
Chili, 1871						325, 000		
England, 1872	1,251,815 pounds	70, 160, 900	181,372 pounds	22, 368½	475,143 pounds	6, 380, 450	92,743 pounds	5, 045, 450
Spain, 1868		72, 800, 000		24, 807		3, 792, 000		2, 509, 000
France, 1868		17, 200, 000		33, 608		16, 420, 000		1, 443, 200
Italy, 1871		5, 500, 000		3, 500		550, 000		
Belgium, 1870	4,330,960 francs	10, 034, 000			4,905,000 francs	2, 121, 000	30,825,940 francs	65, 000, 000
Sweden, 1870		89, 050		975		1, 420, 860		
Norway, annual				3, 700		520, 000		
Districts:								
Clausthal, 1872		8, 479, 200		23, 897½		219, 900		
Halle, 1872		7, 250		23, 158⅔		5, 480, 100		
Bonn, 1872		36, 080, 700		25, 884½		555, 800		11, 013, 550
Breslau, 1872		9, 380, 750		8, 336½				32, 501, 750
Brunswick, 1872	37,083 thaler	300, 700	34,735 thaler	579	61,099 thaler	134, 950	17 thaler	150
Saxony, 1871	528,511 thaler	4, 414, 500	1,850,003 thaler	31, 071½	317,110 thaler	518, 800	26,771 thaler	237, 200
Germany, 1872		58, 733, 100		122, 927⅔		6, 909, 550		44, 752, 650
Bohemia, 1871	497,310 florins	2, 281, 104	1,734,790 florins	16, 274				
Tyrol, 1871	20,100 florins	109, 760			88,460 florins	89, 600	19,170 florins	89, 600
Salsburg, 1871			157 florins	1¼	189,900 florins	224, 000		
Carinthia, 1871	696,360 florins	3, 012, 800						
Styria, 1871	19,780 florins	102, 760	5,850 florins	68				
Krain, 1871	3,320 florins	15, 720					174,800 florins	873, 600
Galicia, 1871							179,000 florins	1, 028, 100
Hungary, 1871		1, 617, 504		20, 128		1, 274, 672		462, 672
Austria-Hungary, 1871		7, 199, 648		36, 471¾		1, 588, 272		2, 454, 032
Russia, 1868		1, 640, 700		17, 895		5, 000, 000		
Total production		330, 755, 146		415, 652⅓		53, 534, 954		167, 411, 014

APPENDIX B.

REGULATIONS FOR THE PURCHASE OF SAXON ORES AT THE WORKS OF THE ROYAL GENERAL SMELTING ADMINISTRATION, FROM "QUARTERLY CRUCIS," 1868.

From the beginning of the "Quarterly Crucis," 1868, the following regulations, coming from the Royal General Smelting Administration, will apply, until further notice, for the purchase of Saxon silver, lead, copper, zinc, sulphur, and arsenical ores.

§ 1.—GENERAL REMARKS.

The purchase of silver, lead, copper, zinc, sulphur, and arsenical ores is conducted according to the tariffs given for each metal delivered *franco* at the works.

§ 2.—CONDITION OF THE ORES IN GENERAL.

The ores must be delivered at the works in such a condition that they may be weighed with accuracy, and allow of the taking of a reliable average assay sample; they must, therefore, be as free from mechanically-combined water as possible. Consequently, ores that are in a slimy condition will not be received.

§ 3.—UNIFORMITY AND FINENESS OF THE ORES TO BE DELIVERED.

It will be demanded of all ores delivered, that they be carefully mixed and possess such a size of grain that not more than 15 per cent. remains back, when sieved on a sieve having 576 meshes to the square inch. Ores which do not come up to this standard will be sent back to the mine, or, as far as is possible, be crushed at the works and charged to the mine. Undressed or partially-crushed ores and lump-ore, the lumps of which are not larger than walnuts, will only be accepted when a special agreement has been made.

§ 4.—DISPOSITION OF THE ORES AT THE SMELTING-WORKS.

All persons wishing to sell ore should inform the head manager, (*oberhüttenvorsteher*,) who will give all the necessary information relating thereto, and inform the seller to which smelting-works the ore should be sent. In this case, however, as far as the business arrangements of the smelting-works will allow, the situation of the mine will be taken into consideration, in order to spare the latter as much as possible on trans-

portation costs. When the ore arrives at the works, the assignment from the head manager must be handed over to the weigher, (*waagemeister*,) also the assay-ticket pertaining to the delivery-assay, (§ 16,) made out by the mine-warden, (*bergwardein.*)

§ 5.—PRESENCE OF THE DELIVERER AT THE WEIGHING OF THE ORE.

The seller must be present when the ore is weighed at the works, or be represented by his agent. When particularly demanded by the deliverer, the weigher is obliged to give the former a written statement of the wet and dry weight of the ore, after the same has been weighed and the moisture been calculated, and the weigher has no right to demand or take payment for the same. Then the mine agent takes the assay samples into his possession for the mine-warden, which have been taken from the ore in his presence and packed in boxes expressly for the purpose, (see § 11,) and must take them in the afternoon of the same day to the city assay laboratory and deliver them to the mine-warden.

§ 6.—TIME OF DELIVERY.

Ore is received at the works every day during the week, excepting Sundays and holidays, and with the exception of Wednesday afternoons, commencing at 12 o'clock. Ores arriving at the works on Sundays will be reckoned to the delivery of the following week.

The determination of the metallic contents of the ores through the purchase and "determination" assays, takes place after every weekly delivery; on the other hand, the settlement with the deliverers of ore only in periods of two to three weeks, the close of which is always on Wednesday noons, 12 o'clock, of the first, third, fifth, seventh, ninth, and eleventh weeks of each quarter.

The deliveries of ore taking place on Thursday of the eleventh week as well as those in the twelfth and thirteenth weeks, belong to the first period of the next quarter, which accordingly has its commencement early Thursday morning of the eleventh week.

If lump-ore is delivered according to § 3, the close of the time of delivery has been fixed on Saturday noon of every week; that is, four days before the close of the current period of delivery; it is here taken into consideration that the preparation of the assay sample and also the determination of the metallic contents of such ores demand more time, and a whole week is therefore allowed for this work.

§ 7.—COMMENCEMENT OF RIGHT OF POSSESSION OF THE GENERAL SMELTING ADMINISTRATION TO DELIVERED ORES.

As soon as the quantity of ore to be delivered has been brought to the works, weighed and dumped, so that it can be easily reached, in order that it may be possible eventually to examine it again, (§ 20,) the mine has lost the right of access to the same, but, notwithstanding, it is

not yet the property of the smelting-works, but is at first to be considered only as a deposit, for which the administration of the smelting-works (*Hüttenadministration*) is responsible.

The delivered ore first becomes the property of the works when there are no differences in the assay results, (§ 19,) or when such differences have been settled according to §§ 19 and 20.

§ 8.—UNIT OF WEIGHT AND ITS DIVISIONS IN THE WEIGHING AND DETERMINATION OF MOISTURE IN THE ORES.

The ore is weighed on scales having arms of equal length, in amounts of 2 cwt., (centnern.) The zollcentner, = 50 kilograms, is the unit of weight and is divided decimally into 100 pounds, and the product into 100 pfundtheils. The weight of the assay weight (the moisture hundred-weight, or centner) made use of for determining the amount of moisture in the ores = 75 grams = 15 pfundtheile. It is also divided into 100 parts.

§ 9.—WEIGHT LIMITS IN WEIGHING THE ORES AND DETERMINATION OF MOISTURE.

The amounts of ore delivered are weighed to within 10 pounds when containing from 1 to 50 pfundtheile* silver; over 50 to 500 pfundtheile to within 1 pound; over 500 to 5,000 pfundtheile to within 0.1 pound; over 5,000 pfundtheile to 0.02 pound. Ores carrying no silver, lead, copper, zinc, sulphur, and arsenic are weighed out to within ten pounds.

It is not allowed to deliver more than 50 cwt. of ore at a time when the same carries 10 pfundtheile or more silver; in consideration of the uniformity of the assay-sample, larger amounts must be divided into amounts of this weight.

Ores carrying less than 10 pfundtheile silver should, on the other hand, be delivered in amounts of 100 cwt. If such ores are delivered in smaller amounts than 100 cwt., the mine from which it came must expect a bill of assay-costs according to § 19. The superintendent (*Hüttenmeister*) has the power, however, to allow the delivery of smaller or larger amounts than above stated.

The amount of moisture contained in the ore will be determined to within 0.5 per cent. without any consideration of its metallic contents or character; but, in the calculation of the wet-weight, smaller weight amounts than given in the commencement of this paragraph will be left out of consideration.

§ 10.—DELIVERY OF THE WEIGHT-STATEMENT BY THE WEIGHER.

During the weighing of every amount of delivered ore at the works, an average assay-sample of several pounds will be taken in the follow-

* One pfundtheile is equal to 0.01 per cent.; 0.01 per cent. = 2 oz. 18 cwt. 4.8 gr. per ton of 2,000 pounds.

ing manner: From every 2 cwt. of the ore $\frac{1}{4}$ to $\frac{1}{2}$ pound will be taken out from the middle by means of a half-hollow cylinder, to which there is a handle attached. The quantity taken out with this instrument is then scattered over two sample-troughs, A and B, which rest near each other, and this is continued until the whole amount of ore delivered has been weighed.

With lump-ore, the assay-sample is either selected according to the cross-method, (*Kreuzprobe*,) or in such a manner that about 10 per cent. of the heap is taken out, crushed, and then a diminished sample taken from the same.

From the sample on the assay-trough A, the weigher immediately determines the amount of moisture.

The "assay-pulverizer" then takes from different parts of the same sample-trough A, by means of an assay-spoon, the amount of ore necessary for the making of the purchase-assay by the warden of the smelting-works, and prepares it in the following manner:

The sample is first carefully dried upon a heated piece of sheet-iron, then the dried sample is pulverized, in an iron mortar, so fine that it will all pass through the covered sieve.

The finely-pulverized assay-sample is then well mixed in the mortar; it is then passed several times through a wire sieve in order to effect a complete mixing, and is then shaken into a small trough, after which it is placed on top of the other two, A and B.

If the ore carries small amounts of native silver, or silver-glance, (see § 12,) the moisture must be determined before the assay-sample is prepared. In pulverizing the same, the little scales of native silver, or silver-glance, which do not pass through the sieve, must be carefully collected and placed in a separate trough, and after the weigher has determined the weight of the pulverized ore, as well as that of the metallic scales, both of the small troughs are to be placed with their respective statements of weight on top of the other two troughs, A and B. The contents of the second trough, B, is kept for the determination-assay.

When the delivery of the day has closed, the weigh-master, in the presence of the mine-agent, takes out a half pound of ore for the purchase-assays, to be made by the mine-warden, from the same sample-trough, A, out of which the samples for the moisture-assays were taken, and all corresponding to the several loads deposited; they are then packed in boxes, not dried and unprepared. The boxes must be returned to the weigh-master carefully cleaned. The boxes are numbered with the corresponding numbers of the loads in the weigh-book and on the assay-sample boards. A ticket must be placed in the boxes, upon which is written the name of the mine from which the ore was delivered, the dry weight, and the quality of the load, all corresponding to the same on the sample-board; also the metallic contents according to the delivery-assay. The sample-boxes, with the statements, are to be handed to the person or persons who have been commissioned to

carry them to the mine-warden at the city-assay laboratory, and must be delivered to him on the same day. The preparation of the assay-samples in the mine-warden's laboratory must be conducted, for the sake of conformity, in the same manner as given above, especially with such ores as carry native silver and silver-glance.

§ 11.—The assay-samples sent to the mine-warden's laboratory, as well as the metallic buttons produced from the same, remain in the possession of the laboratory without charge.

§ 12.—Determination of the metallic contents in delivered ores carrying native silver or silver-glance.

Ores that contain native silver and silver-glance in large amounts, and consequently do not allow of the good pulverization, preparation, and selection of a reliable average assay-sample, must therefore, before being delivered at the smelting-works, be stamped and sieved at the mine, separated into finely-crushed ore, silver, and silver-glance, and separately delivered at the works. While by the delivery of the finely-crushed and mixed part, the assay-sample is taken and prepared as described in § 11, the silver and silver-glance ore must be melted at the works in the presence of the mine-agent, and the silver contents determined by means of the granulation-assay, accompanied at the same time with a determination of the metallic contents in the by-products.

No assay-sample of silver and silver-glance ores delivered at the works is sent to the mine-warden.

13.—Method of assaying and oversight of the manipulation.

The wardens, in making the assays, must follow the methods and rules made by the administration of the smelting-works, and avoid all arbitrary digressions from the same, and, moreover, conform to the regulations from the administration of the smelting-works, regarding the superintendence and oversight of the assaying, as carried out by the designated officers.

§ 14.—The unit of weight and its subdivisions used in the assaying of ores.

The weight of the assay hundred-weight, used in determining the metallic contents of ores, is fixed at 3.75 grams = 0.75 pfundtheil. Its division is decimal, namely, into 100 pounds, and the pound into 100 pfundtheile.

§ 15.—Statement of the metallic contents of an ore.

The metallic contents of an ore are only stated within certain fixed limits.

a. With ores carrying the smallest amount of silver acceptable at the works, that is 1 pfundtheil and up to 25 pfundtheile, their metallic con-

tents will be given on to within 0.5 pfundtheil; with ores carrying more than 25 pfundtheile and up to 200 pfundtheile, the results will be given on to within 1 pfundtheil; and ores assaying higher than 200 pfundtheile, the assay-result will be given on to within 2 pfundtheile.

b. With lead, sulphur, and arsenical ores, the assay-results will be given on to within 5 per cent. for all grades of ore; with lead, however, contained in ore delivered at the works, as blendic ores, to within 1 per cent.

c. With copper and zinc, to within 1 per cent. by all grades of ore

§ 16.—The delivery-assay.

Such assays as are made at the mine-warden's laboratory of the ores prepared at the mines for delivery at the smelting-works, by order of the mine-superintendent, in order to declare their assay-value when delivered at the smelting-works, are called the delivery-assays. The same give, at the same mine, the metals and metalloids the purchase-assay (§ 17) has to determine, and thus stating how many assay-samples it is necessary to prepare. In selecting the assay-sample for the delivery-assay, on behalf of the mine, proper care should be taken, so that no great difference may arise between it and the purchase-assay.

§ 17.—Purchase-assays.

Purchase-assays are those which are made from the samples taken according to § 11 during the weighing of the delivered ore at the smelting-works. For making the same, the sample in the small trough, A, is made use of, (§ 11.) The purchase-assay determines the amount of all purchasable metals and metalloids contained in the ore, following the directions of the statement from the mine of what metals and metalloids are present in the same; also, to determine the amount of lead in all blendic ores, and the amount of zinc contained in all blendic, silver, lead, copper, sulphur, and arsenical ores. The purchase-assay must be made under the supervision of two controlling assayers, the warden of the smelting-works and the mine-warden. Each has his own separate laboratory, the warden of the smelting-works at that place, and the mine-warden in the city of Freiberg.

Accordingly, as the silver-ores are of low or high grade, the assays will be made in duplicate or up to eight times.* The average must be taken of all the separately-weighed buttons. Each of the assayers, in determining the amount of silver in ores, must make two assays with ores containing from 1 to 40 pfundtheile per cwt.; three assays with ores containing from 41 to 80 pfundtheile per cwt.; four assays with ores containing from 81 to 150 pfundtheile per cwt.; six assays with ores containing from 151 to 300 pfundtheile per cwt.; eight assays with ores containing more than 302 pfundtheile per cwt.

* The scorification-assay is entirely used in determining the amount of silver in all ores.

§ 18.—PRESENTATION OF ASSAY-STATEMENT BY THE MINE-WARDEN AND WARDEN OF THE SMELTING-WORKS.

After the close of every weekly delivery, on Saturdays, at 12 o'clock, each of the controlling wardens must deliver, at the "Hüttenraiter Bureau," a full statement of the assay-results as found by actual tests. There the two statements are compared as regards the stated weights and contents. In these statements must be written the name of the mine from which the ore came; the number of loads and their respective dry weights; the quality and the determined amounts of silver, lead, copper, zinc, sulphur, and arsenic, in the exact order, as given in the statement of the weigh-master. The mine-warden must also notify the mine-superintendent of his assay-results in the same order as stated in the weigh-book. In the delivery of native silver and silver-glance, the amount of the contents in silver determined from the smelting, (§ 19,) must also be put down by the warden of the smelting-works as corresponding to the load.

§ 19.—DETERMINATIVE ASSAY.

If there be a difference in comparing the assay-statements of the mine-warden (§ 18) and that of the warden of the smelting-works of the ores delivered of only 0.5 pfundtheil (0.005 per cent. = 1 oz. 9 dwt. 3.84 gr. per ton) silver, the result of the warden of the smelting-works will be taken for computing their contents and the amount to be paid for this metal, (§ 22;) by a difference or one pfundtheil (0.01 per cent. = 2 oz. 18 dwt. 4.80 gr.) per ton of 2,000 pounds) or more of silver, or by differences in lead, copper, sulphur, or arsenic, a determination assay must be made of the special ore-load at the "Hüttenraiter expedition."

A determinative assay of the zinc in zinc-ores will only be made when of the two purchase-assay results the one is over and the other under the limit, for which there is a special tariff for zinc in the zinc-blendic ores, also a reduction in the amount paid for the zinc in blendic ores. The zinc-blendic determinative assay for lead is also only made when the results of the purchase-assays are the one over and the other under 5 per cent.

The results of the determinative assay must be entered in the assay-book, with the difference determined; the ore-load must also be marked with the difference.

The mine-superintendents, as well as the officers of the smelting-works, have the right to demand that a determinative assay be made, when an assay made by them from a sample taken from the ore-load disagrees with the purchase-assay so far that it seems to them it cannot possibly be correct. Such demands for determinative assays must be handed in by the above-named officers in the form of a written statement, (statement of assay-differences,) at the "Hüttenraiter-expedition," before 12 o'clock on Saturday, after the close of the weekly ore-delivery. A statement of this character must contain the name of the smelting-works at

which the ore was delivered, the date of delivery, the name of the mine from which it came, the number of the load, (as numbered in the weigh-journal,) of which the determinative assay is demanded; also the dry weight of same, the quality, and the metallic contents, according to the delivery and purchase assays.

After the officers of the mine and smelting-works have made known the demand for a determinative assay and marked the respective ore-loads, the judge-assayer receives from the "Hüttenraiter," on Saturday evenings of every week, the assay-certificates of the mine-warden, which contain all the ore-loads of the delivery-period of which he has to make determinative assays. The determinative assays are then to be made by the warden in the laboratory of the smelting-works.

The assay-sample in the lower sample-trough B, from which no assay has been made, is used for making the determinative assay. It is taken by the man who pulverizes the assay-samples, under the superintendence of the warden, and carefully prepared according to § 11. Four days are allowed for making all the determinative assays that may be demanded at both smelting-works of a weekly delivery. The days are from Monday to Thursday at the latest.

The results obtained from the determinative assays must be entered by the warden on the assay statement of the mine-warden and immediately sent to the "Hüttenraiter-expedition," where it is open to investigation of the parties concerned until Friday, 12 o'clock, of the same week. At the same time the results must be entered upon the statement of assay-differences, sent in by the mine and smelting-works officers, and, with the other statement, sent to the "Hüttenraiter-expedition," from whence it can be taken away by the mine or smelting-works parties, and if the result differs much between the delivery or load assays, another determinative assay may be demanded, (§ 20.)

When, however, the mine-superintendent demands a determinative assay, in spite of agreement between the purchase-assays of the warden of the mine and smelting-works, within the limits given in the first part of this paragraph, and the correctness of the purchase-assay should be confirmed by the same, the mine must pay for every such determinative assay—for silver, 5 neugroschen; for lead, 10 neugroschen; for copper, 15 neugroschen; for zinc, 15 neugroschen; for sulphur, 15 neugroschen; for arsenic, 15 neugroschen—to the smelting-works at which the ore was delivered, and the bill for the same will be handed in at the close of every three months.

§ 20.—REPETITION OF THE METHOD OF DELIVERY.

If there be a too great a difference between the delivery-assay and the results of the determinative assay demanded by the mine, or between the load-assay and the results of the determinative assay demanded by the smelting-works, then, in the first case, it is allowable for the mine to demand of the repetition of the method of delivery; in

the second case, the smelting-works may demand the same. Moreover, even when no demand has been made for a determinative assay, either party may demand of the repetition of the method of delivery when the difference between the results of the determinative assay is greater than the result of one of the purchase-assays over the other.

In repeating the method of delivery, the entire manipulation of selecting the assay-sample is repeated, by weighing the entire ore-load over again, and selecting of the assay-sample, as already described, after the ore has been well mixed, if deemed necessary, and carted to the scales.

Each of the controlling wardens must carry out the assays according to § 17, and enter the results obtained in their order in the assay-statement book. The weigh-master designates the ore-load as weighed the second time.

The demand for the repetition of the method of delivery on behalf of the mine or smelting-works should be made in the week in which the determinative assay of the ore-load was made, and at the latest on Friday at 12 o'clock, so that the "Hüttenraiter" may arrange that the ore-load may be omitted from the delivery-period of the present week.

When a demand is made on behalf of the smelting-works for the repetition of the method of delivery, the mine-superintendent concerned must be informed of the same by the "Hüttenraiter," or if the mine-superintendent should live too far away from Freiberg, the agent of the mine in the city, who is authorized to attend to the selling of the ore for said mine, must be informed. If this controlling manipulation be demanded on behalf of the mine, the same has to pay the accompanying costs, which are as follows, per load: 2 thaler for a load of 400 centnern, (cwt.) (hundred-weight;) $2\frac{1}{2}$ thaler for a load of over 400 to 500 centnern, and 3 thaler for a load of over 500 to 600 centnern, all in wet weight. Both parties must be ruled by the results of this repeated manipulation, unless the two purchase-assays made from the new assay-samples should show a material difference in their results; if this should be the case with rich ores, it is probable that it comes from the ore not being well mixed. In this case the smelting-works have the privilege of refusing the load until it has been properly prepared for delivery.

§ 21.—Deputyship of the judge-assayer.

If the judge-assayer should be unable to make the determinative assays himself, on account of sickness, or for some other good reason, they are made by some officer of the smelting-works, who is experienced in assaying, and who must follow the instructions of the judge-assayer after having been detailed by the smelting-administration for this duty.

§ 22.—Computation of the ore-prices.

The computation of the metallic contents of the ores is carried out, according to the results of the purchase-assays and determinative

assays, at the "Hüttenraiter-expedition" without any secrecy. The price to be paid for the same is also computed.

The computation of the metallic contents for every calculable metal is carried out by multiplying the dry weight of the ore-load with assay-results; for silver, according to the dry weight as determined according to § 9; but for lead, copper, zinc, sulphur, and arsenic, only to within 10 pounds.

The metallic contents per load are rounded off; with silver, to within 0.5 pfundtheil, (0.005 per cent.=1 oz. 9 dwt. 3.84 gr.;) with lead, zinc, sulphur, and arsenic, to within 0.5 per cent.; and with copper, to within 0.1 per cent.

The computation of the price of the several loads is carried out by multiplying the tariff-price of the different metals by the metallic contents of the ore-load.

When the tariff, however, gives the prices per unit of weight of the ore, the amount to be paid is calculated by multiplying the price in the tariff-list, corresponding to the assay of the ore, by the dry weight of the same.

In case where the silver contents have been determined by smelting all the ore, the tariff-price will be computed by calculating the average contents from the dry weight and assay-results. The doubly-calculated weight, metallic contents, and price to be paid for the ore will be entered in a statement and sent to the mines interested, at the latest on Wednesday of the third, fifth, seventh, ninth, eleventh week of each quarter. It is payable at the treasury of the general smelting administration.

The "Hüttenraiter" must also give to every mine a statement of the amount of ore delivered at the works by each, and it must contain the weight of each load, their metallic contents and assay, and price for every two or three weeks' delivery. This statement, when handed in at the treasury of the general smelting administration by the mine-superintendent, will be accepted, and the amount stated in the same as the calculated price of the ore according to tariff, will be paid.

INFLUENCE OF THE MARKET-PRICE AS REGARDS THE PAYMENT OF LEAD AND COPPER IN THE ORES.

(*a.*) The normal price of lead is taken at 5 thaler per centner (hundred-weight) of the lead sold contained in lead products; and,

(*b.*) For copper, 31½ thaler per centner of copper contained in the copper-vitriol sold.

If the actual net proceeds from selling the lead in lead products by the smelting-works should be more or less in the course of a year, after deduction of the necessary costs of trading, than the net proceeds for the amount of lead sold according to the normal price stated in the first case, the mine shall receive the half of the amount thus gained, and in proportion to the amount of lead delivered by the same as "a lead-

delivery premium." In the second case, however, the mine must share the half of the occurring loss as "a lead-payment restitution," corresponding to the amount of lead contained in ore delivered. The same rule holds good for the copper sold as copper-vitriol.

The calculation of the amount of premium or loss for lead and copper is carried out by the "Hüttenraiter," who not only has to make public, in the form of an extract, the amount of money in the treasury of the general smelting administration, and to give the mines a receipt for the amount of ore delivered at the smelting-works on the eleventh and twelfth week of the "Quartals Lucial," but must also inform the mines interested of the manner in which the premium was calculated at the close of each year, by exhibiting the calculations. The general smelting administration must determine the price to be paid for the metals beforehand for every year, at the end of the same; loss or gain will be equally divided according to amount paid.

Freiberg, March 12, 1868.

"Das Konigliche Oberhüttenamt."

F. M. IHLE.

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OF THE

REPORTS

OF THE

COMMISSIONERS OF THE UNITED STATES

TO THE

VIENNA INTERNATIONAL EXHIBITION, 1873.

PUBLISHED UNDER DIRECTION OF THE SECRETARY
OF STATE BY AUTHORITY OF CONGRESS.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

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